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DREXEL TOWER DATA ANALYSIS FOR WIND SHEAR,(U)
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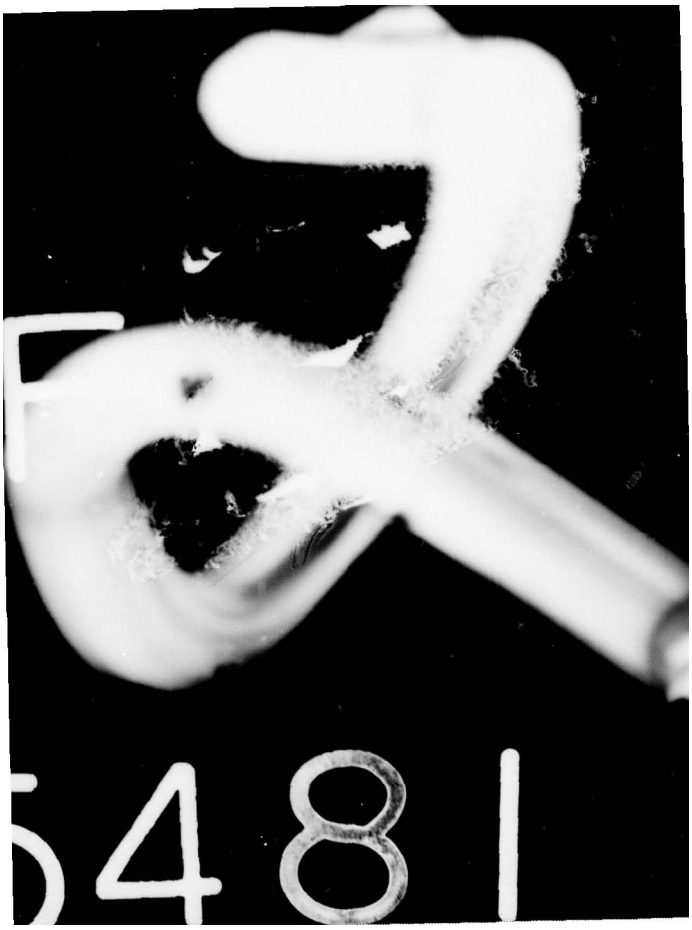
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Report No. FAA-RD-78-136

LEVEL II

DREXEL TOWER DATA ANALYSIS FOR WIND SHEAR

Herman Newstein
Department of Physics and Atmospheric Science
Drexel University
Philadelphia, PA 19104

September 1978
Summary Report

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
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16. Abstract

A Summary Report of Drexel Tower Data Analysis for Wind Shear is provided. Meteorological measurements made over a 7-year period on a 1000 ft tower were analyzed for frequency of occurrence of wind shears at various levels, frequency of occurrence of wind shears with wind directions at various levels, wind shear magnitudes related to temperature differences at various levels and occurrences of wind shears in connection with inversions, fronts, and thunderstorms. It is shown that there is no one unique recognizable situation that will produce wind shears of any specific magnitude.

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METRIC CONVERSION FACTORS

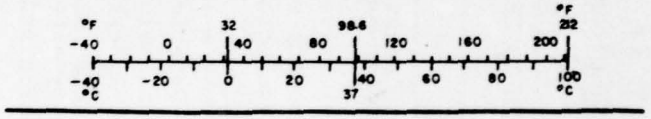
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

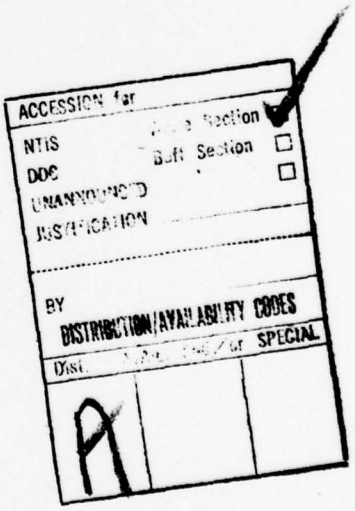
Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

The author's extensive and detailed report, which may be published at a later date, was summarized by Glenn Glassburn, Aviation Weather Branch, Systems Research and Development Service (SRDS) in coordination with Frank Coons of SRDS and Dr. Francis Davis of Drexel University. In order to reduce the report volume, Detailed Wind Shear Analysis sheets were omitted from most of the case studies contained in the report. These omitted sheets are being retained on file at FAA, ARD-450, 800 Independence Ave., Washington, DC 20591.



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Summary Report of Low Level Wind Shear Project Contract DOT - FA77WA-3938
Herman Newstein, Drexel University, Philadelphia, Pa. September 12, 1978

The following is the report based upon the research into the Low Level Wind Shear problem.

I. The Basic Data

A. Site

The observations were made on a 1000 ft. T.V. tower in the North Western section of Philadelphia 7 miles NW of Drexel University and 12 miles N of the Philadelphia International Airport. The tower was owned by Triangle Publications of Philadelphia and supported the antennas for WFIL-TV and KYW-TV stations. The site is in rolling hill terrain about 1/2 mile from the Schuylkill River. The base of the tower is about 300 ft. above sea level, approximately 275 ft. above the river.

B. Instrumentation

The wind instruments were standard Bendix Aerovane Anemometers with three blade propellers which have a starting speed of about 1 kt. The directional accuracy is about $\pm 5^{\circ}$ and speed about ± 1 kt. excluding the influence of the tower in distorting the flow of the air. Each anemometer had its own strip chart recorder and analog integrator and analog to digital converter. The temperature sensors were Leeds and Northrup 100 Ohm copper resistance wire thermometers. The accuracy of the temperature determination was about $\pm .3^{\circ}F$. Each temperature sensor had its own strip chart recorder and analog to digital converter. For further details on the characteristics of the instrumentation and exposure I refer you to the reports I delivered to you: "An Automated Meteorological Instrumentation and Observing System on a 1000 ft. Television Tower." Final Reports I, II, and III dated September 30, 1966; October 17, 1967; and November 1, 1967.

C. Elevation of sensors

Wind measurements were made at 40, 100, 200, 350, 570 and 890 ft. above the ground. Temperature measurements were made at 5 ft. above the ground in addition to the above elevations.

D. Periods of observations and integration duration

As indicated in the above mentioned reports, observations were made for all of the meteorological parameters at either twice per hour or 4 times per hour. The observation began on the hour and continued for 10 minutes during which time the wind direction and speed values were integrated. In the early part of the period the integration time was one minute. At the end of that time the integrated wind values and the observed temperature value were sensed, converted to digital form and punched on two IBM punch cards. The first card contained the wind data and the

second card the temperature data. Each card was identified as to year, Julian date, time in hours and minutes and integration time in minutes and seconds. Missing data for one or more sensors or missing cards were identified. The period of data begins with Nov. 1, 1964 and continues through May 31, 1971.

E. Data reduction

All of the punched cards were reduced to magnetic tape on the Burroughs 5500 computer in the following manner. Each year except 1964-65, which was treated as one year, was written as one file on one reel of magnetic tape. Each pair of punched cards, wind and temperature, was written as one record identified individually by year, date, time and integration time as one record. Identifying information for missing cards was supplied automatically so that there are consecutive records for four observations per hour for every hour and day even though data may have been missing up to the end of the year with the exception that if a block of data at the end of the year including the end was missing, these records were omitted to save space. We therefore had 7 reels of tapes for the periods 1964-65, 66, 67, 68, 69, 70, and 71 which contained all of the information on the origianl punched cards.

II. Statistical Analysis of Data

A. Basic Statistics

All of the data on wind and temperature which had been collected on the T. V. tower during the interval from November, 1964 through May, 1971 and had been punched on IBM cards has been transcribed on to magnetic tape so that the analyses of the data could be processed on the Burroughs 5500 computer. Computer programs were written and checked for the appropriate statistical and quality analyses of the data as will be described below.

An initial program was written and checked out and run which scanned all of the data in the original raw data bank in order to assure that the data were in chronological order, that wind and temperature data observations were properly paired, that missing data were noted and that obviously defective data were removed from the data bank. A listing of the data was then prepared as a preliminary data inventory. With this initial data bank, the process of quality checking and statistical analyses was begun.

As a first step, to comply with the requirements of the work statement, the complete program for the statistical analysis of the data was written and checked out. This program was then run with the basic data bank as input to produce the necessary statistical relationships.

Thirteen sets of statistical relationships, all in identical format, were prepared. Each set was a summary by month (i.e. all Januaries, all Februaries, all Marches, etc.) and finally, the thirteenth set was for the total of all data combined into one set. Each set consisted of the following tables:

1. For each shear level (level 1 used wind data at the 100 ft. and 40 ft. elevations; level 2, the 350 ft. and 100 ft. elevations; level 3, the 570 ft. and 350 ft. elevations; level 4, the 890 and 570 ft. elevation pairs) the frequency of occurrence of shears in one knot intervals was tabulated from 0 to 15 kts., then one group 15-20 kts. and a final group greater than 20 kts. In addition to the above data, there was also included a tabulation of the number of times no shear could have been counted because of lack of data or defective data at one of the level pairs. The frequency of occurrence of no shear meeting the specified criteria as well as the number of shears meeting the criteria and the grand total of observations were also recorded for each level. (Bad data + no shear + shears = total).

2. The frequency of occurrence of shears appearing simultaneously at two, three, and four levels was also tabulated.

3. A two dimensional table presenting the frequency of occurrence of wind shear magnitudes equaling and exceeding the minimum criterion vs. the shear direction in intervals of 10^{o} was prepared by level for each of the four shear levels. Totals horizontally and vertically (i.e., by direction and magnitude) were also summarized. Thus, there are four of these tables for each month and for all months.

4. Another set of four tables, one for each level, was prepared. These present the frequency of occurrence of shear magnitudes of specified intervals vs. the wind direction in 10^{o} intervals for the wind at the lower of the elevation pairs.

5. Another set of four tables, one for each level, was prepared. These present the frequency of occurrence of wind shears by direction in 10^{o} intervals vs. the wind direction of the wind at the lower of the level pair also in 10^{o} intervals.

6. A set of three tables comparing the shear direction at levels 2, 3 and 4 with the wind direction at the 40 ft. level was prepared.

7. A set of three tables comparing the shear direction at levels 2, 3 and 4 with the wind direction at the 100 ft. elevation was also prepared.

8. Another set of four tables, one for each shear level, presents the analysis of wind shear magnitudes with temperature differences in degrees F per 100 ft., as measured between the top and bottom of the shear level.

The temperature intervals are 1°F per 100 ft. from less than -5°F/100 ft. to greater than 10°F/100 ft.

As stated above, items 1 through 8 were prepared separately for all January, all February, all March, etc., and finally, for the entire period 1964-1971 as one set.

B. Quality check of data

Analyses of these data revealed some apparently spurious results which indicated that further quality checking was needed. Since the most important shear data to be examined were those in which exceptionally large shears were present, a further program of extensive quality checking was instituted. This involved the tabulation of the data and time of occurrence of all large shears so that the data which produced these large shears could be examined on the original analog strip chart recordings. A computer program was written that did this and on the basis of these results and comparisons with the original records, digital data that were obviously in error were either corrected in the data bank (e.g., when the digital data did not agree with the analog record, if the sequence of data indicated that the analog record was correct, the digital data in the data bank were corrected, or when the analog records showed that there was an apparent instrumental malfunction as when anemometers froze at one level during an ice storm but not at another warmer level, then the digital data that were erroneous were removed from the data bank). This entailed an extensive and detailed visual analysis of the original strip chart records. The outcome of this program was to produce a set of edited digital data which we consider to the best of our ability to be correct. When this was completed, the sets of tables presenting the overall statistics listed in items 1 through 8 above was prepared using the new data bank. Thus, a final set of statistics was produced satisfying the requirements of Section B, paragraphs 1, 2, 3, 4, 5, and 9 of the Statement of Work.

C. Case studies and analyses

In order to meet the conditions of section B: 6, 7, and 8 of the Statement of Work, additional programs were written to scan through the data bank for the occurrences of Wind Shears in connection with Inversions, Fronts, and Thunderstorms.

A computer program was prepared that produced a list of the occurences of all shears meeting or exceeding the magnitude criteria for each level. This table presented the date, time, wind at each elevation, shear at each level, and temperature at each elevation. From this new data base an analysis was made of the relationship between strong wind shears and inversions. A new list was prepared giving the date, time and elevation of all shears greater than 12 knots or more and the corresponding occurrence of an inversion of 2°F/100 ft. or greater. From this list, it was possible to examine the original analog records of wind and temperature together with the

synoptic data to produce the 10 case studies called for in Section B: 6, 7 and 8.

Another computer program was prepared and run on the new data bank, this time listing the date, time and level of occurrence of wind shears meeting the criteria for level shears magnitude together with the temperature data. In this case the selection was made on the basis of the occurrence of a clockwise wind direction change of at least 60^{o} during a time interval of at most 2 hours. On this basis, it was anticipated that most of the significant frontal passages accompanying wind shears would be identified. On the basis of this list of potential frontal passages, the synoptic charts of those days were examined and a new list of shears accompanied by apparent frontal passages based upon the proximity of the front on the weather chart in relation to the tower data was prepared.

Finally, from the original surface weather observations of the U. S. Weather Service Station at the Philadelphia International Airport which is located 12 miles south of the T. V. tower, a tabulation was made of the dates and times of occurrence of all thunderstorms and lightning that were observed during the entire period November 1964 through May 1971. These data were then compared with the list of occurrence of all shears and a tabulation was made of the concurrence of shears and thunderstorms in the vicinity of Philadelphia. From this list, the 10 most interesting shear-thunderstorm situations was selected for the case studies.

In addition to the above and in connection with the thunderstorm study, cases in which thunderstorms and shears were reported simultaneously were further examined. The magnitude of the temperature drop taken from the analog thermograph record was correlated with the wind shear.

In connection with the synoptic case studies phase of the project, a trip was made to the Climatic Data Center in Asheville, N. C. to determine the availabliity of the pertinent weather and radar data. The microfilm data for the dates and times for the Fronts and Thunderstorms cases were reviewed and 10 cases were selected. The data used included the available surface observations for the Philadelphia International Airport, North Philadelphia Airport, Reading Airport, Pa., and the Willow Grove Naval Air Station, Pa., as well as the WSR-57 radar film from Atlantic City, N.J., the radar range of which covers this area.

III. Synoptic Case Studies

Based upon the analyses stated above, case studies of Frontal, Thunderstorm, and Inversion shear incidents were prepared. These are presented below. The tabulations of one minute shears are self explanatory. Where data boxes are blank, these data were not available.

The case studies presented are as follows:

A. Thunderstorm situations

June 2, 1965	1710 - 1925E
July 18, 1965	1725 - 1855E
October 18, 1967	1740 - 1955E
July 12, 1969	1555 - 1725E
October 20 - 21, 1969	2340 - 0240E
April 2, 1970	1355 - 1710E
April 9, 1970	1425 - 1540E
June 12, 1970	1425 - 1755E
July 31 - August 1, 1970	2255 - 0255E
November 4, 1970	2010 - 2155E

B. Frontal Situations

December 4, 1964	0925 - 1110E
December 4, 1964	1625 - 2210E
February 26 - 27, 1965	2155 - 0110E
February 13, 1966	1255 - 1525E
November 2, 1968	0210 - 0710E
November 12, 1968	0125 - 0410E
November 12, 1968	1010 - 1410E
January 31, 1969	0010 - 0640E
November 23, 1969	0125 - 0225E
November 23, 1969	0640 - 0925E
March 8, 1970	0340 - 0610E
March 8, 1970	1010 - 1210E
April 2, 1970	0840 - 1025E
February 13, 1971	0010 - 1125E

C. Inversions Situations

January 22, 1965	0155 - 0340E
January 22, 1965	0455 - 1010E
February 7, 1965	0810 - 1340E
February 11, 1965	0155 - 0540E
October 3, 1965	0310 - 0740E
December 31, 1965	0040 - 0825E
March 11, 1966	0040 - 0510E
December 17, 1967	0310 - 0840E
September 15, 1967	0010 - 0710E
December 13, 1968	0425 - 0625E
May 8, 1970	2140 - 2325E

IV. Correlation of thunderstorm temperature drop and maximum gusts and sustained wind speeds equal to or exceeding 30 kts. at the 100 ft. and 890 ft. elevations.

These data follow the case studies.

V. Conclusions

After having analyzed the synoptic case studies and shear data, it is clear that there is no one unique recognizable situation that will produce wind shears of any specific magnitude. Wind shears were found to have occurred with and without fronts, with and without thunderstorms and with and without inversions.

It was also found that shears occur momentarily at one level, at several levels simultaneously, for longer durations at one level and for longer durations simultaneously at several levels.

Case of June 2, 1965

On this date, thunderstorms were reported at all four of the surface weather observation stations in the area during the late afternoon. Wind shears meeting the criteria of 9 kts at level 2, 8 kts at level 3 and 10 kts at level 4 were recorded during the approximate time of the thunderstorm occurrences.

A. General Synoptic Situation

At 1600 E, June 2, 1965 a stationary front was situated generally E-W across central Pennsylvania. The line was north of Pittsburgh and Harrisburg and south of Allentown but north of the Philadelphia area. This front moved slowly southward and reached Philadelphia by 2200 E. At 1900 E a trough line oriented NE-SW moved through the Philadelphia area.

The surface weather observations for the Philadelphia International Airport reported falling pressure and light and variable winds until 0800 E after which time the winds became regularly SW and increased to 10 to 12 kts until 1755. At that time a thunderstorm with heavy rain showers was reported with lightning to the NW (in the direction of the tower) moving toward the east. A pressure jump was reported at 1738 E. The thunderstorm at Philadelphia International Airport ended at 1910 E having moved eastward.

During the time of the thunderstorm the winds shifted to northwest with gusts up to 33 kts. After the thunderstorm passage the winds again backed to southwest 10 kts or less. The pressure rose slowly from the lowest point at 1655 E.

The North Philadelphia Airport first reported a thunderstorm at 1810 E and ended it at 1915 E. The wind pattern was similar to that at the

Philadelphia International Airport, light and variable until 0950 E then southwesterly up to 10 kts until the thunderstorm at which time the wind shifted to the northwest briefly but with no gustiness and then back to southwest after the passage of the thunderstorm.

The NAS Willow Grove station first reported thunderstorms at 1711 E which moved toward the southeast. Thunderstorms ended at 1905. Surface winds were light and variable all day until the thunderstorms at which time they were northwest with gusts to 20 kts.

Reading, Pa. had calm winds until the thunderstorm and rainshowers at 1618 E when the wind shifted to north 10 kts, no gusts. The thunderstorms were southwest of the station moving eastward and ended at 1658 E.

Radar film from the Atlantic City WSR-57 radar indicated a line of echoes oriented northeastsouthwest. This line was essentially continuous about 20 miles wide and 150 miles long. The perpendicular distance and direction was 320° and 80 miles. This would place the line of echoes about 30 miles northwest of the tower. By 1720 E the line of echoes had reached the approximate location of the tower. The line of echoes continued it progression southeastward and was passed the tower location by 1928 E.

B. Detailed Analysis of Wind Shears

A detailed analysis of the analog wind records of the Aerovane anemometers was made for the period 1710 E to 1925 E. From these records minute by minute determinations of the wind shears for shear levels 2 (100-350 ft), 3 (350-570 ft), and 4 (570-890 ft) were made, there being no data available for shear level 1. The tabulation of these data are attached.

The record shows that the wind at the anemometer levels was generally from the south-south-west to southwest until 1733 E. At that time the wind at 100 ft began to shift and reached 330° by 1742 E with the wind speed increasing from 8 kts to a maximum of 31 kts. After that the 100 ft wind began to diminish slowly and back to 265° at 7 kts by 1810 E. This was followed by a veering of wind direction without an increase in speed to 355° by 1828 E. Thereafter, the wind at 100 ft remained northerly for the rest of the period until it became calm at 1918 E.

The wind at 350 ft followed a similar pattern. The increase in speed and change of direction occurred about one minute or two earlier than at 100 ft. The wind speed reached 35 kts at 310° at 1738 E. It increased to 37 kts at 320° by 1741 E. Then the wind speed gradually decreased with the direction remaining northwest for the rest of the period. At 570 ft the wind reached 38 kts at 305° at 1738 E and a maximum of 40 kts from 315° at 1742 E thereafter decreasing and backing to 20 kts from 270° by 1806E. After that the direction became 300° to 305° with wind speeds diminishing to calm by 1921 E. An almost identical pattern in time was observed at 890 ft.

The wind shear at level 2 (100 ft-350 ft) first exceeded 9 kts at 1737 E when the shear was 13 kts. The shear magnitude fluctuated above and below the 9 kt value reaching a maximum of 15.7 kt at 1757 E. Then the shear magnitude diminished only intermittently exceeding the 9 kt value thereafter.

At level 3 (350-570 ft) the shear value of 10 kts was reached momentarily at 1743 E. It remained less than 8 kts the rest of the period. Similarly, at level 4 (570-890 ft) a shear of 11.3 kt was reached at 1749 E for one minute and was less than that for the rest of the period.

C. Analysis of Temperature Change and Gustiness

An analysis of the analog temperature and gustiness record for the 100 ft and 890 ft elevations reveals the following. At 1735 E the temperature dropped 14°F at 100 ft and at the same time 15°F at 890 ft. The maximum gust at 100 ft reached 39 kts at 1442 E with no steady wind in excess of 30 kts. At 890 ft the peak gust of 42 kts was observed at 1740 E with the steady wind in excess of 30 kts during the period 1737 E to 1750 E.

160E
190E
220E
70°
40°

DETAILED WIND SHEAR ANALYSIS

Year 1965 Month 6 / Day 2

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est			9	210	14	210	14	200	19	195
1710				5.0	210	2.4	115	5.2	181	
			10	210	12	210	14	200	18	195
711				2.0	210	3.0	156	4.2	178	
			11	210	13	205	11	205	17	195
712				2.3	180	2.0	250	6.5	178	
			10	210	12	210	14	195	17	205
713				2.0	210	3.9	143	4.0	242	
			9	215	12	210	13	200	18	200
714				3.1	196	2.4	140	5.0	200	
			12	215	12	205	13	200	18	195
715				2.1	120	1.5	155	5.2	182	
			10	205	11	195	14	195	19	195
716				2.1	139	3.0	195	5.0	195	
			8	210	9	200	13	200	17	195
717				1.8	149	4.0	200	4.2	179	
			8	215	10	200	13	190	16	200
718				3.1	158	3.6	161	3.9	225	
			9	215	11	200	11	200	16	195
719				3.3	155	0	0	5.1	184	
			9	210	12	200	12	200	17	195
720				3.5	174	0	0	5.2	183	
			8	210	12	205	14	200	19	195
721				4.1	195	2.3	173	5.2	181	
			7	210	12	210	13	200	17	195
722				5.0	210	2.4	140	4.2	179	
			8	215	13	210	13	200	18	195
723				5.1	202	2.3	115	5.2	182	
			9	215	12	205	13	200	17	200
0724				3.5	179	1.5	155	4.0	200	

DETAILED WIND SHEAR ANALYSIS

Year 19 65/ Month 6 / Day 2

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est			9	225	10	210	13	195	17	205
1725				2.7	149	4.2	157	4.8	233	
			8	220	12	215	12	205	18	205
726				4.1	205	2.1	120	6.0	205	
			8	220	13	215	13	205	18	205
727				5.1	207	2.3	120	5.0	205	
			9	225	12	215	14	205	19	215
728				3.5	189	3.0	161	5.8	240	
			9	230	10	220	12	215	17	215
729				1.9	166	3.2	194	4.0	215	
			8	230	9	225	11	215	16	215
730				1.2	191	2.7	179	5.0	215	
			7	250	9	235	14	220	17	220
731				2.9	196	5.8	196	3.0	220	
			7	265	10	240	13	230	16	225
732				4.7	201	3.6	201	3.3	205	
			8	275	11	250	13	235	14	230
733				5.1	208	3.7	185	1.5	183	
			9	290	12	270	13	245	14	250
734				4.7	229	5.5	178	1.5	297	
			10	300	15	285	13	260	14	260
735				5.9	259	6.4	165	1.0	260	
			14	305	17	300	15	275	17	275
736				3.3	278	7.2	182	2.0	275	
			14	305	27	305	23	290	25	300
737				13.0	305	7.6	176	4.6	360	
			21	305	35	310	38	305	37	305
738				14.2	317	4.4	261	1.0	125	
			22	325	30	310	33	310	35	310
1739				10.4	277	3.0	310	2.0	310	

DETAILED WIND SHEAR ANALYSIS

Year 1965 / Month 6 / Day 2

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est			20	325	29	315	33	315	37	310
1740				9.9	295	4.0	315	5.0	275	
			27	325	37	320	37	315	37	315
741				10.4	307	3.2	228	0	0	
			31	330	37	325	40	315	36	310
742				6.7	301	7.4	254	5.2	172	
			28	325	36	320	40	305	32	305
743				8.5	303	10.7	244	8.0	125	
			22	325	33	320	33	315	32	300
744				11.3	310	2.9	228	3.5	211	
			21	330	27	315	33	310	36	295
745				8.6	276	6.5	289	9.5	231	
			20	325	29	315	30	305	33	295
746				9.9	295	5.2	231	6.3	239	
			20	325	27	315	31	305	31	300
747				8.1	290	6.4	258	2.7	213	
			20	325	28	305	31	305	36	300
748				11.5	268	3.0	305	5.8	272	
			17	315	24	310	26	305	36	295
749				7.2	298	3.0	260	11.3	272	
			16	295	25	300	30	300	35	285
750				9.2	304	5.0	300	9.8	273	
			16	275	23	300	29	290	29	280
751				10.9	339	7.5	258	5.1	195	
			14	275	21	280	25	285	24	280
752				7.2	290	4.5	309	2.4	167	
			15	280	22	285	22	285	27	280
753				7.2	296	0	0	5.4	259	
			14	285	23	290	24	280	30	295
1754				9.1	298	4.2	209	6.4	304	

DETAILED WIND SHEAR ANALYSIS

Year 1965 / Month 6 / Day 2

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est			14	280	24	285	25	285	32	285
1755				10.1	292	1.0	285	7.0	285	
			14	300	27	285	27	285	33	285
756				14.0	270	0	0	6.0	285	
			12	300	27	285	28	280	32	285
757				15.7	274	2.6	215	4.8	316	
			14	285	25	280	27	280	32	280
758				11.1	274	2.0	280	5.0	280	
			13	275	23	275	26	275	31	275
759				10.0	275	3.0	275	5.0	275	
			14	260	20	270	24	275	28	280
800				6.7	291	4.4	298	4.6	307	
			10	275	18	280	23	275	27	285
801				8.1	286	5.3	258	5.9	328	
			7	270	17	280	22	275	26	285
802				10.2	287	5.3	259	5.8	326	
			6	285	16	280	21	280	23	280
803				10.0	277	5.0	280	2.0	280	
			8	285	16	280	18	280	22	280
804				8.1	275	2.0	280	4.0	280	
			7	280	17	280	18	275	21	275
805				10.0	280	1.8	221	3.0	275	
			6	280	15	275	20	270	20	275
806				9.0	272	5.2	256	1.7	3	
			9	295	15	275	19	275	20	280
807				7.2	250	4.0	275	2.0	337	
			7	300	15	275	20	275	21	280
808				9.2	256	5.0	275	2.1	338	
			6	270	15	280	20	280	21	285
1809				9.2	287	5.0	280	2.1	343	

DETAILED WIND SHEAR ANALYSIS

Year 1965 Month 6 / Day 2

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est			7	265	15	280	18	280	22	290
1810				8.4	292	3.0	280	5.3	326	
			7	285	12	285	17	280	21	290
811				5.0	285	5.2	268	5.2	325	
			5	295	11	285	15	285	20	290
812				6.1	277	4.0	285	5.2	304	
			4	320	11	300	15	285	19	295
813				7.4	289	5.2	252	5.0	327	
			3	315	11	290	15	290	20	295
814				8.4	281	4.0	290			
			3	300	11	300	15	290	20	290
815				8.0	300	4.6	265	5.0	290	
			5	315	10	305	15	290	18	290
816				5.2	295	5.9	264	3.0	290	
			6	330	11	310	14	290	18	295
817				5.7	289	5.3	244	4.2	312	
			5	350	11	315	16	295	17	295
818				7.5	292	6.8	261	1.0	295	
			4	355	11	310	16	300	17	300
819				8.7	291	5.5	280	1.0	300	
			5	340	11	310	16	300	18	295
820				7.1	289	5.5	280	2.5	261	
			6	345	11	315	16	300	15	290
821				6.5	288	6.1	272	2.9	185	
			5	345	12	320	15	300	15	290
822				7.8	304	5.5	252	2.6	205	
			6	330	13	315	14	300	16	290
823				7.4	303	3.7	233	3.3	242	
			7	345	13	315	14	300	16	285
1824				7.8	288	3.7	233	4.4	229	

DETAILED WIND SHEAR ANALYSIS

Year 1965 / Month 6 / Day 2

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est			7	345	13	315	13	300	16	285
1825				7.8	288	3.4	218	4.8	241	
			7	345	13	320	13	305	16	285
826				7.3	296	3.4	223	5.8	235	
			7	350	12	320	13	300	16	280
827				6.9	289	4.5	233	5.8	230	
			7	355	11	325	13	305	16	285
828				6.1	290	4.6	250	5.8	235	
			8	350	12	325	14	305	15	285
829				5.8	290	4.9	249	5.1	216	
			8	350	13	320	14	305	14	285
830				7.2	287	3.7	238	4.9	205	
			7	345	12	320	14	305	15	295
831				6.4	292	3.9	253	2.7	232	
			7	345	12	315	14	295	14	300
832				6.9	284	4.9	239	1.2	28	
			6	350	13	315	14	245	13	300
833				8.8	292	4.8	227	1.5	68	
			7	355	13	315	14	300	11	300
834				8.9	285	3.7	233	3.0	120	
			9	355	13	315	14	300	10	305
835				8.4	272	3.7	233	4.1	108	
			9	355	12	315	14	300	10	305
836				7.7	266	3.4	248	4.1	108	
			9	0	12	315	14	305	10	310
837				8.5	267	3.0	261	4.1	113	
			9	0	13	315	13	305	10	310
838				9.2	271	2.3	220	3.2	109	
			9	0	13	320	12	300	9	310
1839				8.4	277	4.5	207	3.5	94	

DETAILED WIND SHEAR ANALYSIS

Year 1965 Month 6 / Day 2

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est			9	0	13	320	12	300	8	310
1840				8.4	277	4.5	207	4.4	101	
			9	350	13	320	13	300	9	310
841				6.9	279	4.5	220	4.4	99	
			8	350	13	320	15	300	12	305
842				7.3	287	5.3	242	3.2	101	
			7	355	13	320	15	300	13	300
843				8.3	291	5.3	242	2.0	120	
			7	355	13	320	15	300	13	300
844				8.3	291	5.3	242	2.0	120	
			7	345	13	315	14	300	12	305
845				7.8	288	3.7	233	2.3	93	
			7	350	13	315	14	300	11	310
846				8.3	286	3.7	233	3.7	89	
			8	355	13	315	13	305	10	310
847				8.6	278	2.3	220	3.2	109	
			9	350	13	315	13	305	10	295
848				7.6	272	2.3	220	3.6	154	
			9	350	13	315	12	305	10	290
849				7.6	272	2.4	195	3.5	173	
			9	350	13	315	11	305	7	295
850				7.6	272	2.9	176	4.3	141	
			8	345	13	310	12	305	8	295
851				7.9	275	1.5	175	4.4	144	
			8	345	12	310	11	305	9	290
852				7.1	270	1.4	173	3.3	170	
			7	340	11	310	11	300	9	305
853				6.1	275	1.9	215	2.2	99	
			7	340	10	315	10	300	7	295
1854				4.7	276	2.6	218	3.1	131	

DETAILED WIND SHEAR ANALYSIS

Year 1965 / Month 6 / Day 2

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est			6	345	10	315	9	300	7	300
1855				5.7	283	2.7	196	2.0	120	
			5	340	9	310	9	300	7	300
856				5.3	282	1.6	215	2.0	120	
			5	325	10	305	10	295	8	300
857				5.6	287	1.7	210	2.2	96	
			4	330	10	310	11	295	8	305
858				6.4	298	2.9	232	3.4	91	
			5	340	10	310	9	300	7	300
859				6.2	286	1.9	184	2.0	120	
			6	335	11	310	8	305	6	305
900				6.1	285	3.1	143	2.0	125	
			6	355	11	305	8	310	9	305
901				8.5	272	3.1	112	1.2	271	
			6	355	10	305	7	310	8	305
902				7.7	268	3.1	114	1.2	274	
			6	355	9	305	7	315	8	310
903				6.9	263	2.4	95	1.2	279	
			6	355	8	305	7	310	8	300
904				6.2	257	1.2	94	1.6	252	
			6	5	8	305	6	305	7	295
905				7.2	259	2.0	125	1.5	251	
			6	5	7	305	6	300	7	285
906				6.6	253	1.2	152	2.0	233	
			5	5	7	305	6	295	8	285
907				6.2	261	1.5	169	2.3	254	
			4	5	6	305	6	295	8	280
908				5.3	264	1.1	210	2.7	245	
			4	10	6	305	5	295	8	275
1909				5.6	265	1.4	164	3.7	248	

DETAILED WIND SHEAR ANALYSIS

Year 1965 / Month 6 / Day 2

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est			4	10	5	305	4	295	7	280
1910				4.9	257	1.3	158	3.3	362	
			4	0	5	305	4	295	6	280
911				4.3	255	1.3	158	2.4	254	
			4	5	5	305	4	295	6	270
912				4.6	256	1.3	158	2.9	235	
			4	5	5	305	4	300	5	270
913				4.6	256	1.1	144	2.5	218	
			4	5	5	305	4	300	5	265
914				4.6	256	1.1	144	2.9	212	
			3	10	4	305	4	300	5	260
915				3.9	260	0.4	213	3.2	207	
			3	25	4	305	3	300	5	260
916				4.6	265	1.0	140	3.3	224	
			3	35	4	305	3	300	5	250
917				5.0	268	1.0	140	3.8	213	
			0	0	3	305	3	295	4	245
918				3.0	305	0.5	210	3.1	197	
			0	0	3	305	2	285	5	245
919				3.0	305	1.3	156	3.7	225	
			0	0	2	305	2	280	6	235
920				2.0	305	0.9	203	4.8	218	
			0	0	0	0	0	0	5	230
921				0	0	0	0	5.0	230	
			0	0	0	0	0	0	5	235
922				0	0	0	0	5.0	235	
			0	0	0	0	0	0	5	235
923				0	0	0	0	5.0	235	
			0	0	0	0	0	0	4	235
924				0	0	0	0	4.0	235	
			0	0	0	0	0	0	5	235
1925				0	0	0	0	5.0	235	

Case of July 18, 1965

On this date, thunderstorms were reported at all four surface weather reporting stations in the Philadelphia area. These thunderstorms all occurred during the late afternoon of July 18, 1965. Wind shears reached or exceeded the minimum specified criteria at levels 2 and 3 but not at level 4. There was no shear data for level 1.

A. General Synoptic Situation

At 1300 E, July 18, 1965, there was a low pressure center over northeastern Pennsylvania. A stationary front extended from northeast to southwest from the coast of Maine, through the low center along a line east of Pittsburgh and then along the Kentucky-Indiana border. A warm front extended from the low center southeastward through northern New Jersey and off the coast. At 1600 E the low had moved over New York City and the stationary front had become a cold front and had moved to near Reading, Pa. thence southwestward through central Kentucky. The warm front moved northeastward.

By 1900 E the cold front was just about upon Philadelphia. The wind shift at Philadelphia International Airport occurred at 1755 E with the first thunderstorm which began at 1749 E. By 2200 E the cold front had moved to the coast of New Jersey.

The surface weather observations at Philadelphia International Airport indicated layers of clouds, restricted visibility and light southwesterly winds during the morning. The winds became southerly with gusts to 18 kts by 1555 E at which time towering cumulus clouds were reported N-E to S. The first thunderstorm began at 1605 E and ended 1618 E having moved eastward. A second thunderstorm began at 1749 E. This one caused the wind

to gust to 35 kts and had heavy rain showers. Cumulonimbus clouds with lightning in the clouds was reported to the northwest at 1730 E. This is in the direction of the tower.

The sequence of weather at the North Philadelphia Airport was similar to that at Philadelphia International Airport. The first thunderstorm began at 1615 E and ended at 1710 E having moved E. A second thunderstorm to the west (also in the direction of the tower) began at 1825 E and moved N and ended at 1915 E. At this station the surface winds gusted to 25 kts from the northwest. The NAS Willow Grove Station also reported towering cumulus clouds and then a thunderstorm which began at 1803 E and ended at 1943 E. The surface winds were from 220° at 15 kts gusting to 27 kts.

Finally, Reading, Pa. also reported thunderstorms beginning at 1620 E and moving eastward and ending at 1810 E. The winds at Reading during the thunderstorm were west at 8 kts with no gusts.

The sequence of occurrence of the first thunderstorm at the four stations was:

1605 E	Philadelphia International Airport
1610 E	Reading, Pa.
1615 E	North Philadelphia Airport
1803 E	NAS Willow Grove

The radar records at Atlantic City, N. J. WSR-57 radar indicate a line of echoes along the N. J. shore line at 1400 E with some scattered echoes west of Reading. By 1607 E the echoes west of Atlantic City were becoming larger and more general in area with an echo over the location of the tower. These scattered echoes organized themselves along a diffuse line oriented NE-SW by 1700 E. The line extended about 200 miles in length and about 100 miles wide with an open area over the

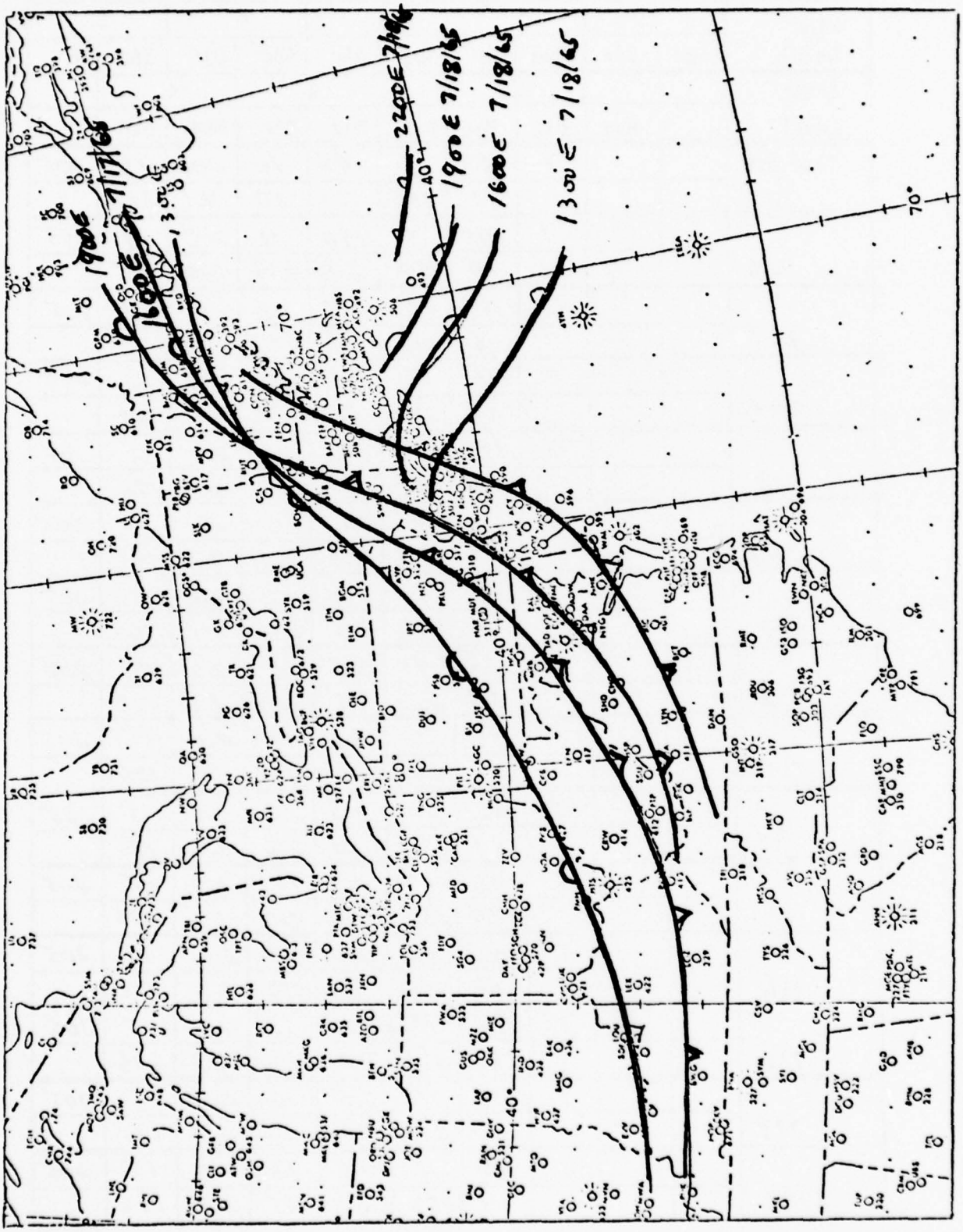
Philadelphia area. This line moved in a southeasterly direction with individual echoes moving eastward and an echo over Philadelphia and the tower at 1744 E. The echoes continued until after 1954 E.

B. Detailed Analysis of Wind Shears

No one-minute shears met the minimum criteria of 9 kts at level 2 until 1756 E. At that time the shear at level 2 was 12.2 kts. After that time, one-minute shears continued to exceed 9 kts with occasional values less than that until 1835 E. 8 kts was reached at level 3 only twice, at 1812 E and again at 1819 E. 10 kts was never reached at level 4.

C. Temperature and Gust Analysis

The analysis of the thermograph and aerovane gust recorder records for this case indicate the following: At 1535 E the temperature at 100 ft dropped 8°F. The maximum gust near that time was 20 kts and that occurred at 1540 E and the maximum gust near that time was 20 kts at 1612 E. Neither elevation experienced sustained wind speeds in excess of 30 kts.


2200E 7/18/65
1900E 7/18/65
1600E 7/18/65
1300E 7/18/65

DETAILED WIND SHEAR ANALYSIS

Year 1965 Month 7 / Day 18

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est			7	185	7	195	10	200	14	205
1725				1.2	280	3.1	211	4.1	217	
			7	190	8	190	11	205	14	205
726				1.0	190	3.9	237	3.0	205	
			7	185	8	195	11	205	14	205
727				1.6	243	3.4	229	3.0	205	
			7	185	8	195	10	210	13	205
728				1.6	243	3.1	252	3.2	189	
			7	190	8	195	11	210	15	205
729				1.2	226	3.9	242	4.2	192	
			6	190	8	200	11	210	14	205
730				2.3	226	3.4	234	3.2	188	
			5	195	9	200	12	210	13	205
731				4.0	206	3.5	236	1.5	160	
			6	195	9	205	12	210	14	205
732				3.3	224	3.1	224	2.3	178	
			6	195	9	205	12	210	15	205
733				3.3	224	3.1	224	3.2	186	
			6	195	10	210	12	210	15	205
734				4.5	230	2.0	210	3.2	186	
			6	195	10	210	13	210	15	205
735				4.5	230	3.0	210	2.3	176	
			6	195	10	210	13	210	15	205
736				4.5	230	3.0	210	2.3	176	
			7	195	11	210	13	210	15	205
737				4.6	233	2.0	210	2.3	176	
			7	195	11	215	13	210	15	205
738				5.0	243	2.3	185	2.3	176	
			8	195	11	215	13	210	15	205
1739				4.4	253	2.3	185	2.3	176	

DETAILED WIND SHEAR ANALYSIS

Year 1965 / Month 7 / Day 18

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est			7	200	12	215	13	210	15	205
1740				5.5	234	1.5	165	2.3	176	
			8	205	12	215	13	210	16	205
741				4.4	234	1.5	165	3.3	185	
			8	200	13	215	14	215	16	205
742				5.7	236	1.0	215	3.3	157	
			9	205	13	215	14	215	16	205
743				4.4	236	1.0	215	3.3	157	
			9	205	13	215	15	215	17	205
744				4.4	236	2.0	215	3.4	156	
			10	200	14	215	16	215	17	205
745				5.1	246	2.0	215	3.0	139	
			10	205	14	215	16	215	17	205
746				4.5	238	2.0	215	3.0	139	
			10	205	15	215	16	215	17	205
747				5.4	234	1.0	215	3.0	139	
			11	205	15	215	15	215	17	205
748				4.6	240	0	0	3.4	156	
			11	210	15	220	15	215	17	205
749				4.6	245	1.3	128	3.4	156	
			10	215	15	225	16	220	18	205
750				5.4	244	1.7	169	4.9	147	
			11	220	16	230	17	225	18	210
751				5.5	250	1.8	172	4.7	140	
			12	235	17	235	20	230	21	215
752				5.0	235	3.4	204	5.4	143	
			17	260	19	250	24	250	24	230
753				3.7	197	5.0	250	8.3	150	
			17	260	22	265	28	260	25	240
1754				5.3	281	6.4	243	9.7	142	

DETAILED WIND SHEAR ANALYSIS

Year 1965 / Month 7 / Day 18

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est			18	265	24	265	32	265	32	255
1755				6.0	265	8.0	265	5.6	170	
			18	260	30	265	29	270	36	265
756				12.2	272	2.8	19	7.6	245	
			18	275	30	270	33	275	31	265
757				12.2	263	4.1	315	5.9	160	
			18	285	27	285	31	270	40	270
758				9.0	285	8.6	215	9.0	270	
			18	275	28	280	30	270	36	270
759				10.2	289	5.4	207	6.0	270	
			19	285	33	280	35	270	36	270
800				14.2	273	6.3	204	1.0	270	
			19	270	28	270	30	270	33	270
801				9.0	270	2.0	270	3.0	270	
			18	280	28	275	31	270	36	270
802				10.2	266	4.0	232	5.0	270	
			15	280	26	275	27	280	36	280
803				11.1	268	2.5	344	9.0	280	
			15	285	24	285	29	285	35	285
804				9.0	285	5.0	285	6.0	285	
			18	290	28	290	34	295	37	290
805				10.0	290	6.6	317	4.3	247	
			22	300	37	295	38	295	39	285
806				15.2	288	1.0	295	6.8	208	
			20	300	31	305	38	300	39	295
807				11.2	314	7.6	279	3.5	224	
			20	305	31	300	35	300	37	295
808				11.2	291	4.0	300	3.7	240	
			19	305	28	305	35	300	35	295
1809				9.0	305	7.5	281	3.1	208	

DETAILED WIND SHEAR ANALYSIS

Year 1965 Month 7 / Day 18

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est			19	305	27	305	29	300	33	295
1810				8.0	305	3.2	252	4.8	263	
			13	300	25	305	26	295	33	295
811				12.1	310	4.6	223	7.0	295	
			13	295	20	305	27	295	29	290
812				7.5	322	8.1	270	3.2	242	
			10	290	22	300	27	295	28	295
813				12.3	308	5.4	274	1.0	295	
			12	295	22	300	23	295	27	295
814				10.1	306	2.2	234	4.0	295	
			10	295	20	295	21	300	27	300
815				10.0	295	2.1	358	6.0	300	
			12	300	16	300	21	300	27	300
816				4.0	300	5.0	300	6.0	300	
			11	300	18	300	20	305	28	305
817				7.0	300	2.6	342	8.0	305	
			9	300	17	300	21	310	28	305
818				8.0	300	5.2	345	7.3	291	
			8	305	16	305	24	310	27	305
819				8.0	305	8.2	320	3.7	271	
			9	330	17	315	23	305	26	300
820				8.6	299	6.9	280	3.7	267	
			10	310	17	315	19	295	20	305
821				7.1	322	6.6	232	4.7	350	
			8	330	18	305	19	295	20	305
822				11.3	288	3.4	227	3.5	74	
			9	325	18	305	18	295	19	295
823				10.0	287	3.1	210	1.0	295	
			9	320	17	305	17	305	19	305
1824				8.6	289	0	0	2.0	305	

DETAILED WIND SHEAR ANALYSIS

Year 1965 / Month 7 / Day 18

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est			9	330	17	310	17	305	18	305
1825				9.1	290	1.5	218	1.0	305	
			9	350	16	315	15	315	16	305
826				10.1	284	1.0	135	2.9	240	
			8	0	15	315	14	320	15	310
827				10.9	284	1.6	86	2.7	247	
			8	5	14	320	12	320	14	310
828				10.1	286	2.0	140	3.0	266	
			8	35	13	320	11	320	13	310
829				13.4	285	2.0	140	2.9	269	
			7	35	12	325	11	315	13	305
830				11.6	291	2.2	204	2.9	264	
			7	20	11	320	10	310	13	305
831				9.6	281	2.1	196	3.2	289	
			6	15	10	315	10	310	13	300
832				8.7	278	0.9	223	3.6	271	
			6	15	10	310	10	305	12	300
833				9.2	274	0.9	218	2.2	277	
			5	5	10	300	9	305	11	300
834				9.1	270	1.3	83	2.2	279	
			5	20	9	295	8	295	11	300
835				9.9	265	1.0	115	3.1	313	
			4	25	8	295	8	295	11	295
836				8.9	268	0	0	3.0	295	
			4	30	7	290	8	295	11	295
837				8.6	263	1.2	326	3.0	295	
			4	30	7	285	8	290	10	290
838				8.9	259	1.2	321	2.0	290	
			3	15	7	285	7	290	10	285
1839				7.6	262	0.6	18	3.1	274	

DETAILED WIND SHEAR ANALYSIS

Year 1965 / Month 7 / Day 18

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est			3	355	7	285	6	295	9	285
1840				6.6	260	1.5	61	3.3	266	
			4	340	7	295	6	295	9	275
841				5.0	261	1.0	115	3.9	244	
			5	325	8	300	6	295	10	270
842				4.1	269	2.1	134	5.2	241	
			6	325	8	300	8	290	11	275
843				3.6	255	1.4	205	3.9	243	
			6	335	8	300	9	295	12	285
844				4.6	252	1.2	261	3.5	259	
			6	335	8	305	10	300	16	295
845				4.1	258	2.2	281	6.1	287	
			6	330	8	310	10	300	17	305
846				3.1	269	2.5	267	7.1	312	
			6	340	8	310	12	305	17	305
847				4.1	263	4.1	295	5.0	305	
			6	350	8	310	14	310	18	300
848				5.1	261	6.0	310	4.9	270	
			7	355	9	315	14	315	18	305
849				5.8	264	5.0	315	4.9	275	
			8	0	9	320	15	320	18	305
850				5.9	259	6.0	320	5.2	257	
			8	0	9	330	16	320	18	310
851				4.5	267	7.3	308	3.6	259	
			8	5	11	335	15	320	17	310
852				5.7	291	5.2	287	3.4	261	
			7	5	11	335	14	320	16	315
853				6.1	300	4.4	280	2.4	284	
			7	5	12	335	14	320	15	315
854				6.9	304	3.9	268	1.6	266	
			7	10	12	335	14	320	14	320
1855				7.4	302	3.9	265	0	0	

Case of October 18, 1967

In this case, thunderstorms were reported in the late afternoon. These thunderstorms were associated with the passage of a low pressure center and frontal system. Data available for shear levels 1 and 2 showed shears in excess of 6 kts and 9 kts respectively during that time. There was no data for levels 3 and 4.

A. General Synoptic Situation

At 1600 E on October 18, 1967 a low pressure center was located just about over Reading, Pa. A cold front extended from the low south southeastward across Delaware and into the Atlantic east of Cape Hatteras. Another cold front extended from the low northward west of Albany, N. Y. into the St. Lawrence Valley. Also a trough extended from the low south-south-westward into western North Carolina. Philadelphia was in the southerly warm sector flow.

By 1900 E the low center had moved to the northeastern corner of Pennsylvania and the cold front had moved eastward over Philadelphia and lay across New Jersey northeast of Atlantic City. The trough had disappeared. By 2200 E, the low pressure center was north of Albany, N. Y. and the cold front was well off the Atlantic Coast.

The Philadelphia International Airport reported low clouds, rain, drizzle and fog during the morning. The surface winds were southerly, less than 10 kts until 1343 E when they became southeasterly 12 to 14 kts with gusts to 18 kts. By 1723 E rainshowers had begun. Thunderstorms with heavy rainshowers were reported by 1804 E with winds southwesterly to 23 kts with gusts to 40 kts. These ended by 1834 E though the wind was gusty to 32 kts the rest of the day.

The weather at Reading was similar to that at the Philadelphia International Airport. Rain showers and fog during the morning cleared by 1356 E. Winds were southeast up to 10 kts. At 1559 E the pressure fell rapidly and surface winds became gusty reaching a maximum of 35 kts at 1820 E with the beginning of a thunderstorm. The thunderstorm ended at 1935 E with the thunderstorm moving eastward.

Radar film records from Atlantic City, N. J. showed a wide spread area of echoes that included the tower location at 1340 E. These echoes moved northeastward and cleared out of the tower area by 1400 E. At 1500 E spots of echoes began to appear from 25 to 75 miles west of the tower. These became a line of echoes oriented NW-SE by 1800 E. This line extended from 125 miles NW of the tower to about 100 miles south. This line moved eastward and by 1700 E the southern end was 50 miles south of the tower. By 1738 E the line was just a few miles SW of the tower and by 1800 E it was upon the tower. This line now extended radially outward from Atlantic City to 175 miles NW with its axis covering the tower location. By 1900 E, the line of echoes had diminished in size and had moved well northeast out of the tower area.

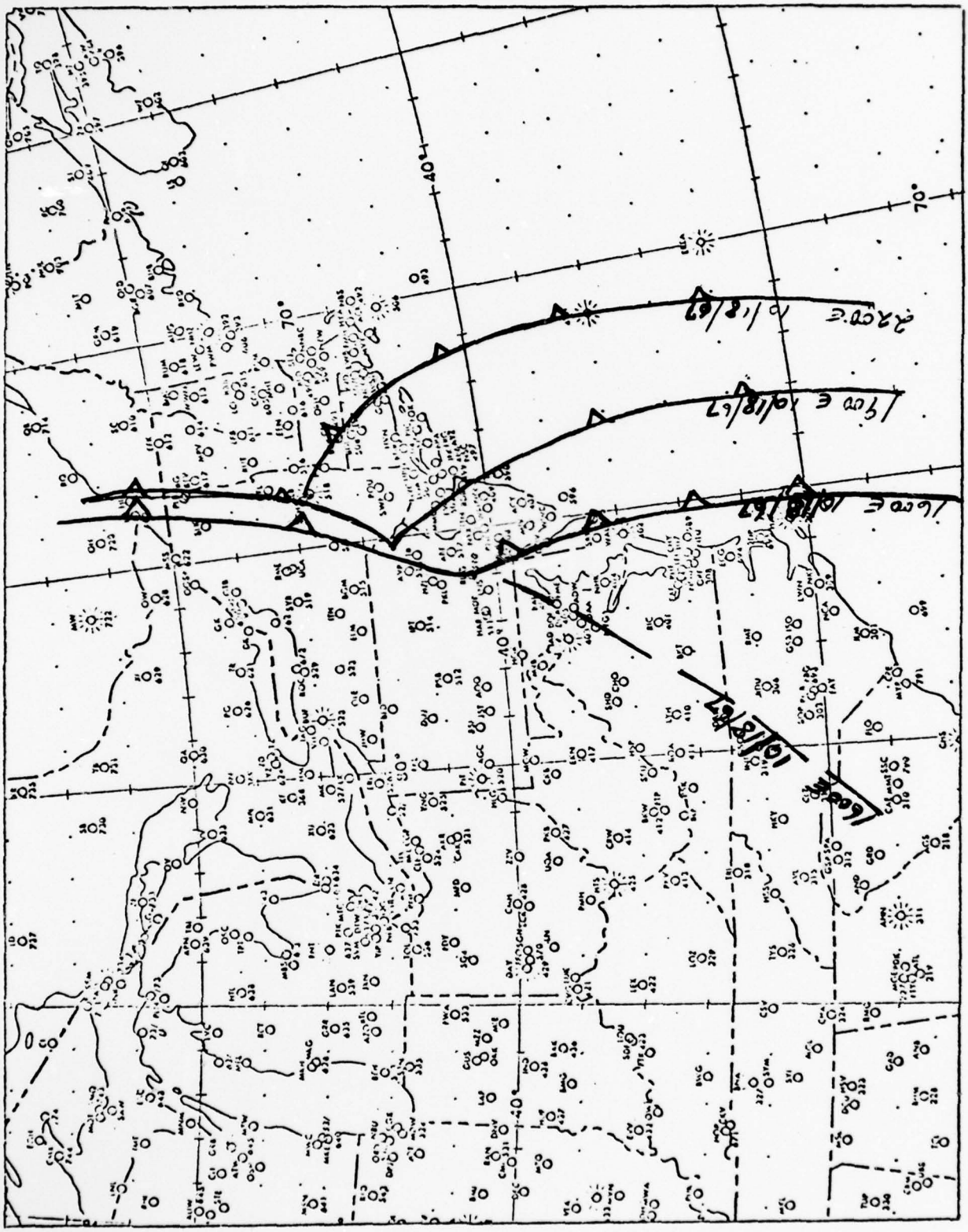
B. Detailed Analysis of the Wind Shear

A minute by minute determination of the wind shear at levels 1 and 2 was computed from the Aerovane anemometer strip chart recordings for the 40 ft, 100 ft and 350 ft elevations. There were no wind data available for the upper two levels. A tabulation of these shears for the period 1740 E to 1955 E is attached. These tabulations show that wind shears of greater than 6 kts were reached at level 1 off and on from 1756 E until the end of the period. The maximum shear was 17.7 kts from 118°

at 1816 E. Shears of greater than 9 kts were observed at level 2 intermittently until 1934 E. The largest shear was 13.1 kts and this occurred at 1841 E and 1934 E.

C. Temperature and Gustiness Analysis

At the 100 ft elevation, at 1815 E the temperature fell 9°F while the maximum gust of 42 kts occurred at 1817 E. Winds greater than 30 kts were observed from 1817 E to 1818 E. At the 890 ft elevation the temperature drop was 11°F and this occurred also at 1815 E. The maximum gust associated with the temperature drop was 58 kts and this occurred at 1818 E. Wind speeds of 30 kts or greater at 890 ft occurred more or less continuously from 1700 E to 1933 E.



Detailed Wind Shear Analysis sheets omitted from this case study to reduce volume.

Case of July 12, 1969

On this date a frontal wave south of Philadelphia with accompanying thunderstorms was associated with the occurrence of wind shears between 1555E and 1725E.

A. General Synoptic Situation

At 1300E a frontal wave was located at Norfolk, Va. The cold front extended south westward through Central North Carolina and western South Carolina. The warm front lay southeastward east of Cape Hatteras. The low pressure area extended northward into south eastern Pennsylvania. By 1600E, the low center had moved east north eastward to 100 miles east of Wallops Island and the cold front moved south eastward about 50 miles. By 1900E, the center was over Bermuda and the cold front entered the coast near Cape Hatteras. During this time, Southeastern Pennsylvania was under the influence of the overrunning air with easterly flow below the frontal surface.

Rain showers had persisted all morning until near noon at the Philadelphia International Airport with north east to south east surface winds of 8 kts. or less. The rain ended earlier at 1150E at North Philadelphia Airport and at 0830E at Willow Grove and at 0536 at Reading. North Philadelphia and NAS Willow Grove had light easterly winds while Reading winds were light and variable.

The rain showers ended in the early afternoon for several hours and the surface winds shifted to SW 7 to 8 kts. Thunderstorms were reported at the Philadelphia International Airport at 1610E and continued until 1710E moving eastward. With the thunderstorms the wind shifted to NW to North 15 kts. with gusts to 30 kts. After the thunderstorm the wind returned to SW 7 kts. or less.

The same situation occurred at the North Philadelphia Airport without the strong and gusty wind. The thunderstorm began at 1640E and ended at 1705E. At the NAS Willow Grove, the thunderstorm began at 1602E and ended at 1640E with very light winds. The thunderstorm at Reading began at 1455 and ended at 1453E. Both Philadelphia International Airport and Reading had heavy rainshowers and gusty winds with the thunderstorms.

B. Detailed Analysis of Wind Shears

A minute by minute tabulation of the wind shear for levels 1 and 2 was made from the analog aerovane wind records for the time interval 1555E to 1725E. No data was available for the upper levels. This tabulation is attached. The records show that at 1607E the shear at level 1 reached 9.2 kts. and continued above 6 kts. until 1615E. The shear then diminished for the remainder of the period.

At level 2, the shears reached 12.2 kts. at the same time as level 1, and remained above 9 kts. until 1617E after which the shears at this level also decreased.

C. Analysis of Temperature and Gust Data

A detailed analysis of the analog thermograph and gust recorders showed that at 1600E, the temperature at both the 100 ft. and 890 ft. elevations dropped 10^{o}F. The maximum gust at the 100 ft. elevation reached 37 kts. at 1607E while the maximum gust at 890 ft. was 50 kts. at 1606E. The sustained wind never reached 30 kts. at the 100 ft. level but reached or exceeded 39 kts. from 1605E to 1613E at the 890 ft. level.

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of October 20-21, 1969

In this case, thunderstorms associated with the passage of a cold front over this area were reported by all four surface weather observation stations in the area. In conjunction with these thunderstorms and front, wind shears meeting or exceeding the minimum criteria of 6 kts at level 1 (40-100 ft), 9 kts at level 2 (100-350 ft) and 8 kts at level 3 (350-570 ft), were reported at various times between 2340 E, October 20, to 0240 E, October 21, 1969.

A. General Synoptic Situation

At 2200 E, October 20, 1969 a low pressure center was located over north eastern Maine. A cold front extended from the low southwestward through Pennsylvania west to Wilkes Barre and Harrisburg into central Tennessee. Philadelphia was on the southwesterly warm sector flow. By 0100 E, October 21, 1969 the cold front had just passed over Philadelphia with associated thunderstorms. At 0400 E, October 21, 1969 the cold front was just upon Atlantic City, N. J.

On the evening of October 20, 1969 the clouds and visibility began to lower at Philadelphia International Airport due to rainshowers and smoke by 2355 E. The surface winds were southwesterly 220-240° 11 kts increasing to 15 kts by midnight. Thunderstorms began at 0022E, October 21, with heavy rainshowers. These thunderstorms lasted off and on with light to moderate showers until 0215 E after which the storms moved southeasterly. With the thunderstorms, the winds shifted to 290° and 340° increasing in speed to over 20 kts with the maximum gust from 050° at 35 kts.

At the North Philadelphia Airport, surface winds south to southsouthwest became gusty and gusts reached 30 kts by 2350 E of October 20, 1969.

Thunderstorms were reported with moderate rain at 0030 E, October 21, 1969 and these moved southeastward and ended at 0150 E. Surface winds became westerly 290°-15 to 17 kts with gusts to 40 kts with the thunderstorm.

The surface weather at NAS Willow Grove was similar to that at the North Philadelphia Airport except the winds were gusty all afternoon and evening of October 20, 1969. Thunderstorms began at 0020 E, October 21, 1969 and ended at 0125 E. The surface wind shifted to east with gusts to 22 kts.

The weather at Reading, Pa. was similar to that at the Philadelphia International Airport except the thunderstorms began earlier, 2308 E, and ended 2345 E, October 20, 1969. Below is a tabulation of the time of beginning of the first thunderstorm at the four stations.

2308 E	October 20, 1969	Reading, Pa.
0020 E	October 21, 1969	NAS Willow Grove, Pa.
0022 E	October 21, 1969	Philadelphia International Airport
0030 E	October 21, 1969	North Philadelphia Airport

The radar film record of the WSR-57 radar at Atlantic City, N. J. shows the beginning of a line of echoes 150 miles northwest of Atlantic City, 100 miles northwest of the tower at 2028 E, October 20, 1969. This line of echoes was oriented NE - SW and was located 50 miles northwest of the tower by 2200 E. Echoes were over the tower location at about 0000 E of October 21, 1969.

B. Detailed Wind Shear Analysis

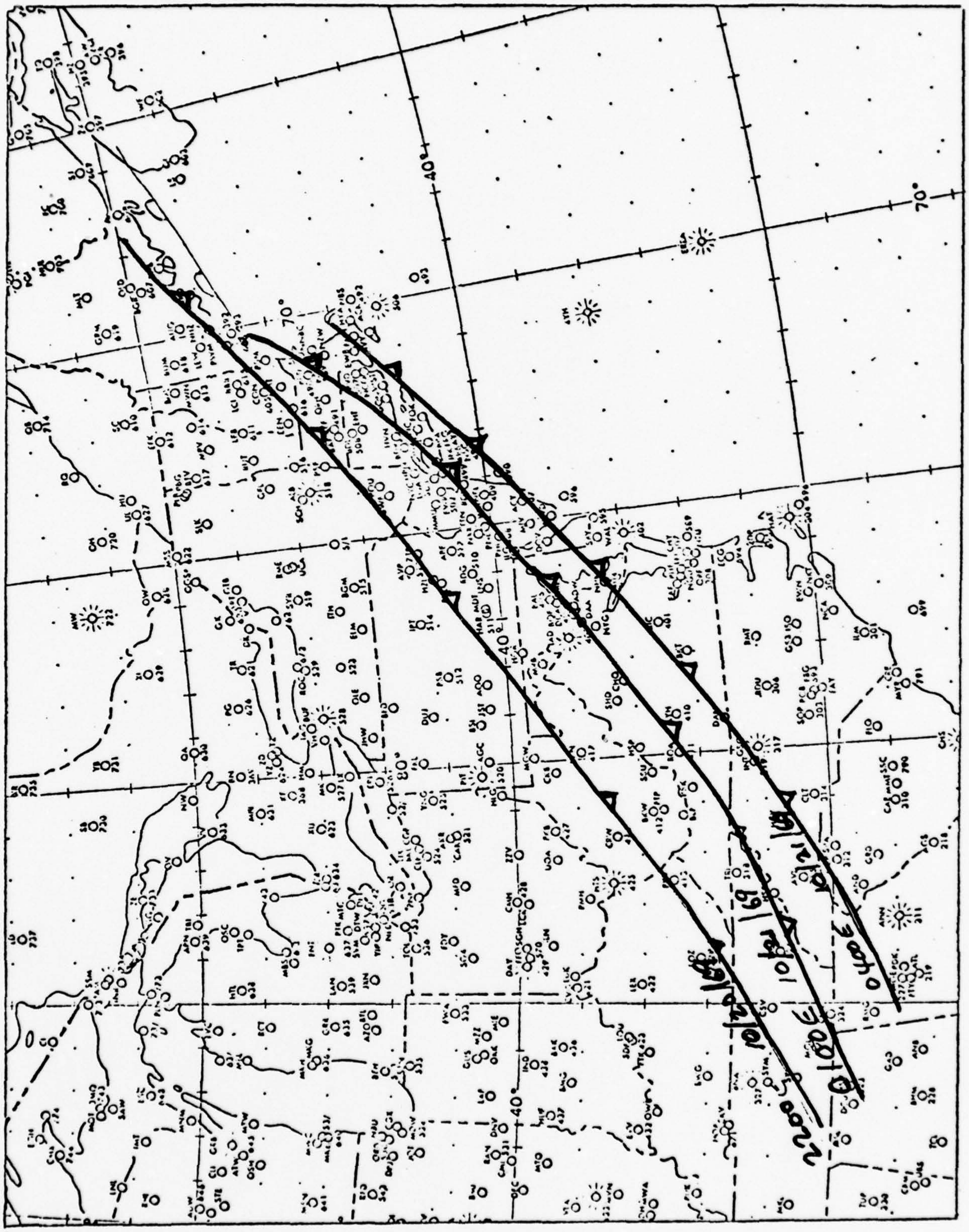
A minute by minute determination of the wind shear at all levels was made from examination of the Aerovane Analog wind records. Data for all levels was available. The tabulation of the wind and shears for the time interval from 2340 E October 20, 1969 to 0240 E, October 21, 1969 is attached. These records show that shears first met the minimum requirement

at 2341 E at level 2. No shears meeting the requirement were then observed until 2351 E at level 3. From 0010 E to 0020 E shears at level 2 again reached 9 kts or more while shears at level 3 reached more than 8 kts at 0013 until 0016.

Intermittently, thereafter, shears exceeded the minimum at level 1, 2, and 3. Level 4 reached 16.3 kts for one minute at 0032 E. After 0042 E, shears no longer reached the minimum at any level.

C. Temperature and Wind Gustiness Analysis

At 0030 E, October 21, 1969 the temperature at the 100 ft elevation fell 8°F with the peak gust reaching 43 kts at the same time. There were no sustained winds of 30 kts or over at any time at that elevation. At the 890 ft elevation, the temperature fell 9°F at 0010 E, 20 minutes before the 100 ft elevation. The peak gust at 890 ft was 48 kts and this occurred also at 0030 E. Sustained winds of 30 kts or more were recorded from 0013 E to 0018 E and from 0027 E to 0033 E at elevation 890 ft.



Detailed Wind Shear Analysis sheets omitted from this case study to reduce volume.

Case of April 2, 1970 (B)

On this date, shears exceeded the minimum criteria during the period 1355 E to 1651 E. These shears occurred in conjunction with a cold frontal passage and the occurrence of thunderstorms.

A. General Synoptic Situation

At 1300 E an approaching cold front was just west of Harrisburg, Pa. The warm front had already passed north of Philadelphia and Philadelphia was in the warm sector flow. By 1600 E, the cold front had passed east of Philadelphia.

The surface weather observations for Reading, Pa. show that a thunderstorm with moderate rainshowers occurred at 1222 E and ended at 1240 E as the storm moved eastward. Surface winds were variable NE through SE less than 8 kts as the warm front approached then became SW 14 kts with gusts to 26 after the warm front passed but before the cold front. The wind shifted to WNW 12 kts at 1430 E with the passage of the cold front. The weather cleared and there were no thunderstorms with the cold front.

The Philadelphia International Airport had showers with SE gusty surface winds until 1433 E. A thunderstorm with heavy rainshowers and SW winds 30 kts with gusts to 40 kts was reported at 1433 E. This continued until 1500 E. The cold front passed at 1730 E with rapid clearing and gusty winds to 50 kts.

The North Philadelphia Airport had similar weather to Philadelphia. Thunderstorms began at 1435 E and ended at 1505 E. Surface winds were southerly with gusts to 35 kts. The cold front wind shift occurred at 1650 E with rapid clearing and surface gusts to 54 kts at 1900 E.

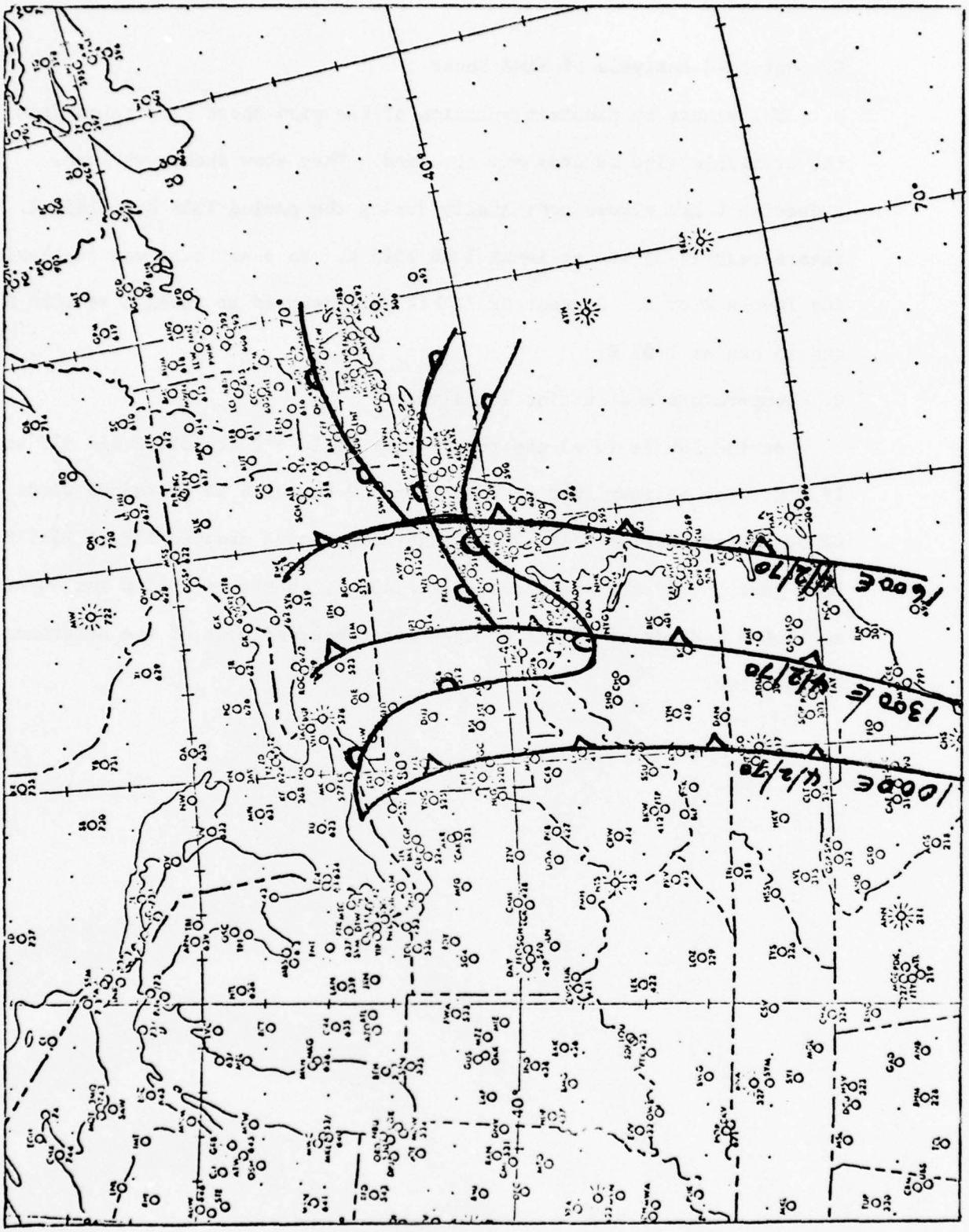
The Atlantic City, N. J. weather radar showed a strong echo 25 miles west of the tower at 1150 E. These echoes reached the tower location by 1313 E.

B. Detailed Analysis of Wind Shear

The minute by minute tabulation of the wind shear data taken from the available wind records are attached. They show shears at level exceeding 6 kts almost continually during the period 1356 E to 1651 E. Shears reached 28 kts at level 1 at 1515 E. No shear data was available for levels 2 or 3. A shear of 11 kts was observed at level 4 at 1510 E and 15 kts at 1703 E.

C. Temperature and Gustiness Analysis

At the 100 ft level the temperature fell 5°F at 1515 E and 9°F at 1650 E. The maximum gust at 1515 E was 38 kts with no sustained winds of 30 kts or greater. At 890 ft, the temperature cropped 8°F at 1515 E. Peak gusts of 60 kts were reached at 1408 E, 45 kts at 1515 E and 50 kts at 1704 E. Winds of 30 kts or over were observed most of the afternoon and evening.


1600E 4/2/78
1300E 4/2/78
1000E 4/2/78

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of April 9, 1970

On this date, thunderstorms occurred with the passage of a cold front. In conjunction with the thunderstorms and frontal passage, there were shears in excess of the minimum requirements at levels 1 and 4 during the period 1425E to 1540E.

A. General Synoptic Situation

At 1300E on April 9, 1970 a northeast-southwest cold front at Altoona, Pa. was moving eastward. It was preceeded by a trough of lower pressure over Philadelphia at that time. By 1600E the cold front was between Philadelphia and Atlantic city.

The surface weather observations for Reading, Pa. indicate that the front passed over that station about 1255E when the wind shifted from 240° to 280° and became gusty to 20 kts. Rain showers began at 1340 and ended at 1415E. Gusts increased to 30 kts. during the afternoon. The cloud layers at 4000 ft. and above cleared rapidly after 1555E.

The Philadelphia International Airport had multiple cloud layers all morning. Visibility had been restricted by rainshowers and smoke then cleared to unrestricted at 1155E. The wind was southwest 17 kts. with gusts to 24. At 1505E a thunderstorm and rainshower was reported the wind shifted to 270° at 35 kts. and gusted to 52 kts. The thunderstorm moved eastward and ended at 1522E.

The North Philadelphia Airport had weather similar to the Philadelphia International Airport but no thunderstorms. Moderate rain was reported at 1520E.

There was no radar information available for this situation.

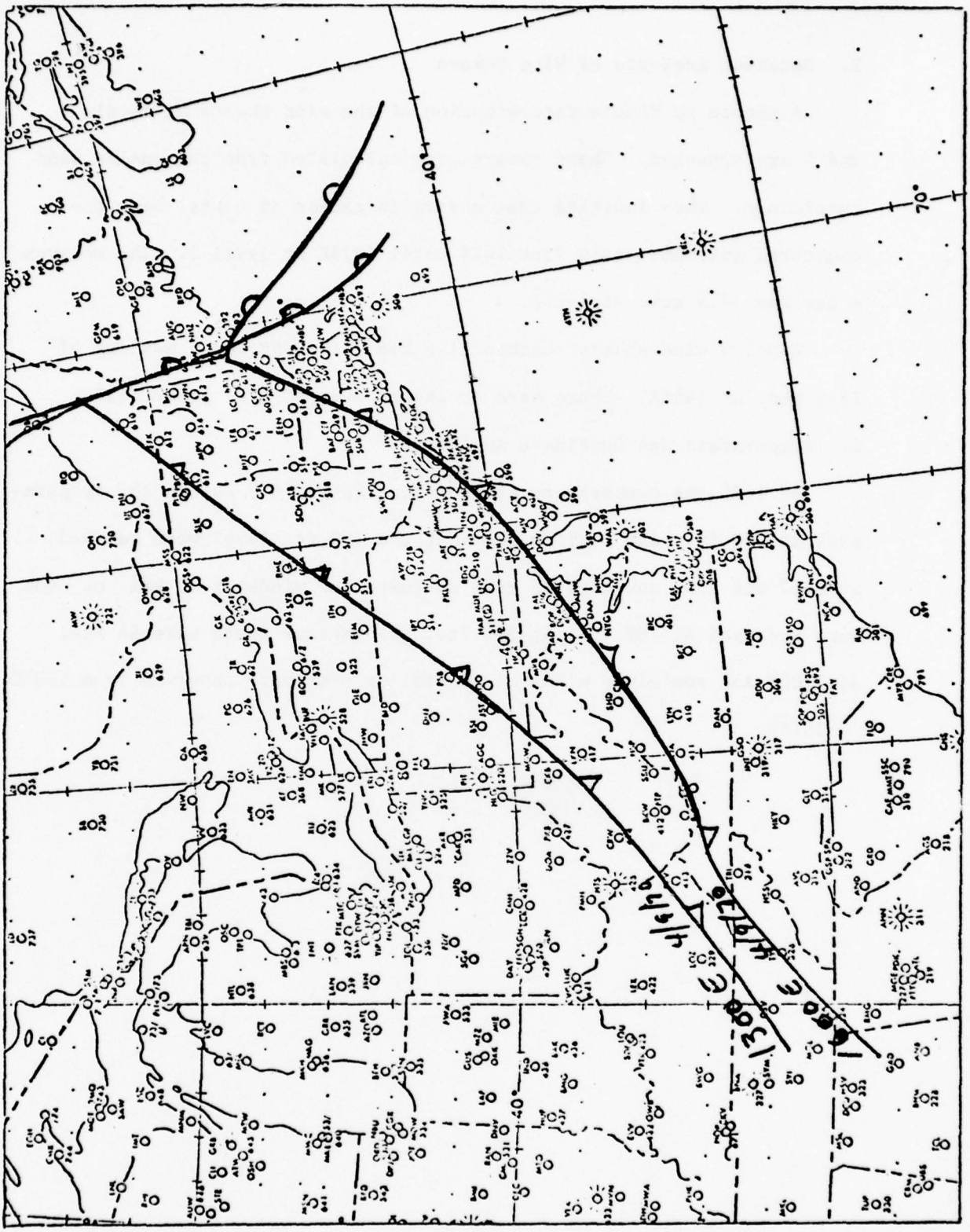
B. Detailed Analysis of Wind Shears

A minute by minute determination of the wind shears at levels 1 and 4 are attached. These shears were calculated from the analog wind recordings. They indicate that shears in excess of 6 kts. were encountered intermittently from 1425 until 1516E at level 1. The maximum shear was 14.9 kts. at 1457E.

Level 4 wind shears reached 11.5 kts. at 1455E and a maximum of 18.9 kts. at 1456E. There were no shears over 10 kts. after 1457E.

C. Temperature and Gustiness Analysis

At 1455 the temperature at 100 ft. dropped 16^{o}F as did the temperature at 890 ft. The maximum gusts at the 100 ft. level were reached at 1457 and 1505 and were 33 kts. no sustained winds of 30 kts. or over were reported at 100 ft. At 890 ft., the maximum gusts were 44 kts. at 1506E and sustained winds of 30 kts. or over were observed from 1505E to 1514E.


1300 MST 4/4/73

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of June 12, 1970

On this date, wind shears in excess of the minimum requirement were observed at levels 1 and 4 between the times of 1425E and 1755E. These shears occurred in conjunction with thunderstorms that were related to a frontal passage.

A. General Synoptic Situation

A cold front that lay east west across northern Pennsylvania moved southward across the Philadelphia area. The surface winds at Philadelphia International Airport were southwest 10 kts. at 1455E. They then shifted to 330°-18 kts. with gusts to 30 kts. with a thunderstorm which began at 1533E. Thunderstorms continued with gusty winds until 1816E. These thunderstorms were accompanied by heavy rainshowers and maximum gusts of 34 kts. The thunderstorms were west and northwest of the station and moved south eastward.

Reading, Pa. reported thunderstorms at 1610E toward the southwest, moving east. The thunderstorm ended at 1710E. The winds remained light, less than 12 kts. during the entire period.

North Philadelphia airport reported thunderstorms beginning at 1445E and ending at 1640E and then again at 1744E and ending at 1920E. Surface winds increased to 20 kts. but no gusts were reported.

The NAS at Willow Grove had weather similar to North Philadelphia. The first thunderstorms began at 1410E and had moderate rainshowers. This ended at 1535E with maximum gusts to 15 kts. The second group of thunderstorms started at 1750E with no gusts but heavy rainshowers. These ended at 1845E.

No radar data was available for this situation from Atlantic City.

B. Detailed Analysis of Wind Shears

A minute by minute tabulation of wind shears for the period 1425E to 1755E is attached. This tabulation shows that wind shears of 6 kts. were reached at 1448E at level 1 and continued intermittently until 1610E. The shear reached 103 kts. at level 4 for one minute at 1456E then decreased. The shear at level 4 reached 26.6 kts. at 1515E with occasional occurrences of 10 kts. or more thereafter until 1628E.

C. Temperature and Gust Analysis

The occurrences of temperature drops at 100 ft. and 890 ft. in relation to wind gusts are presented in the table below.

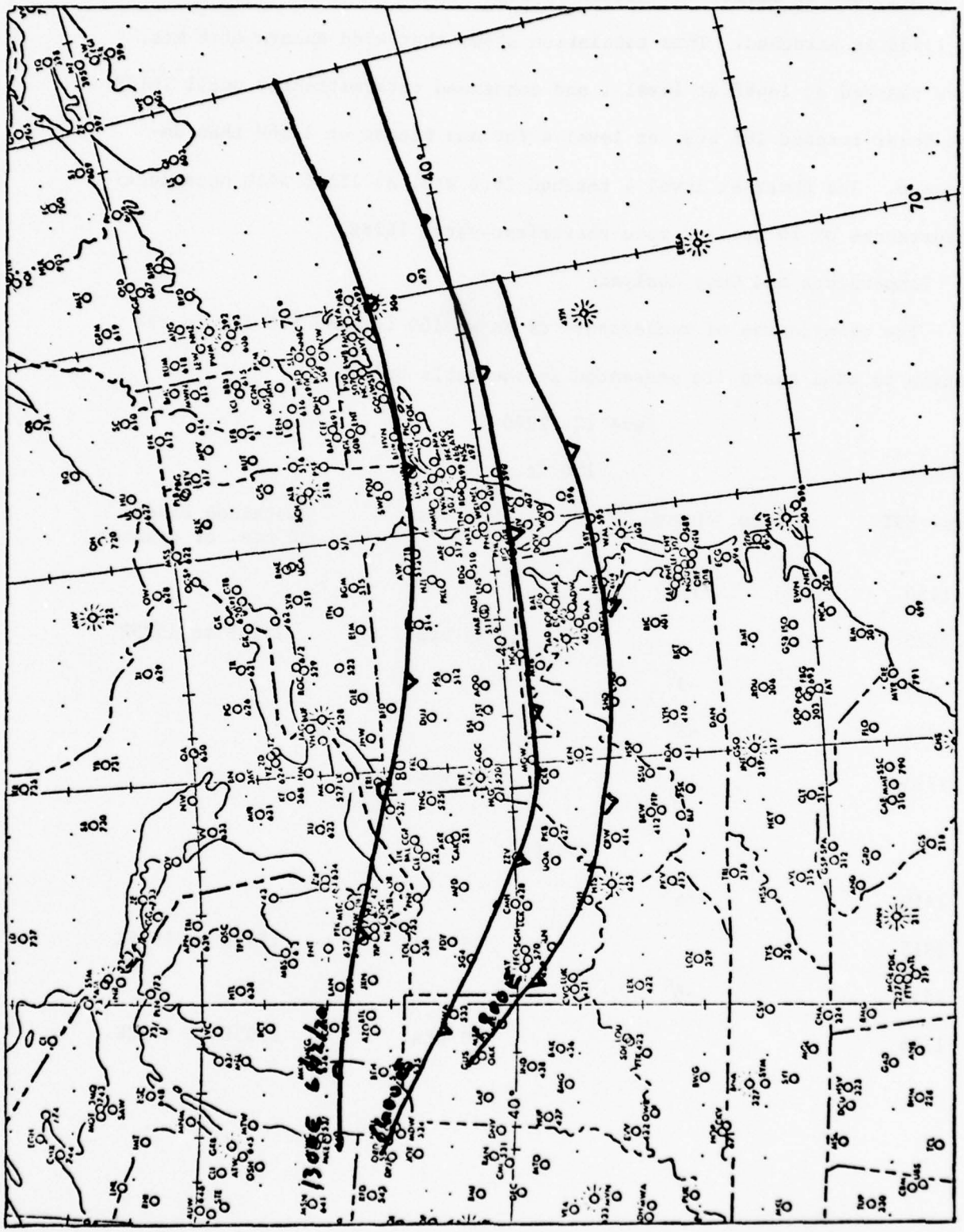
June 12, 1970

100 ft.

Time EST	Temp. change °F	Max Gust	Sustained winds 30 kts. or greater
1450	-19°		
1525		50 kts.	1524E to 1525E
1635	-3°		
1710	-8°		
1735		34 kts.	

890 ft.

1450	-16°		
1515		48 kts.	1503E to 1515E
1635	-6°		
1716		49 kts.	1705E to 1738E



Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of July 31-August 1, 1970

In this case, wind shears occurred in connection with a broad trough of low pressure over the eastern U. S. Thunderstorms were reported at all four surface weather observing stations before and after midmight of the morning of August 1, 1970. Wind shears meeting the mimumum criteria were observed for only 1 minute at level 4.

A. General Synoptic Situation

A trough of low pressure was located over eastern U. S. at 2200 E on July 31, 1970. The trough was followed by a NE-SW cold front through central Michigan. During the next six hours, the cold front moved southeast at an average speed of about 15 kts. The trough of low pressure persisted over southeastern Pennsyl vania.

There were multiple layers of clouds during all of the day of July 31, and into August 1, 1970. Surface winds were southeasterly less than 10 kts at all of the stations. Thunderstorms had been reported shortly after noon of July 31, 1970 at North Philadelphia Airport and NAS Willow Grove but only rain showers at Philadelphia Airport. At 2020 E Reading, Pa. reported thunderstorms with light rain and maximum gusts to only 18 kts. These thunderstorms lasted till 0430 E August 1, 1970.

The Philadelphia International Airport reported thunderstorms with heavy rainshowers beginning at 2325 E on July 31, 1970 and continuing until 0230 E August 1, 1970. The maximum gusts were 24 kts.

North Philadelphia Airport had thunderstorms with slight rain showers beginning at 0000 E and ending at 0135 E while NAS Willow Grove thunderstorms began at 2348 E July 31 and ended 0420 E August 1, 1970. These thunderstorms all moved east and southeastward. Surface gustiness was essentially nonexistent with these storms.

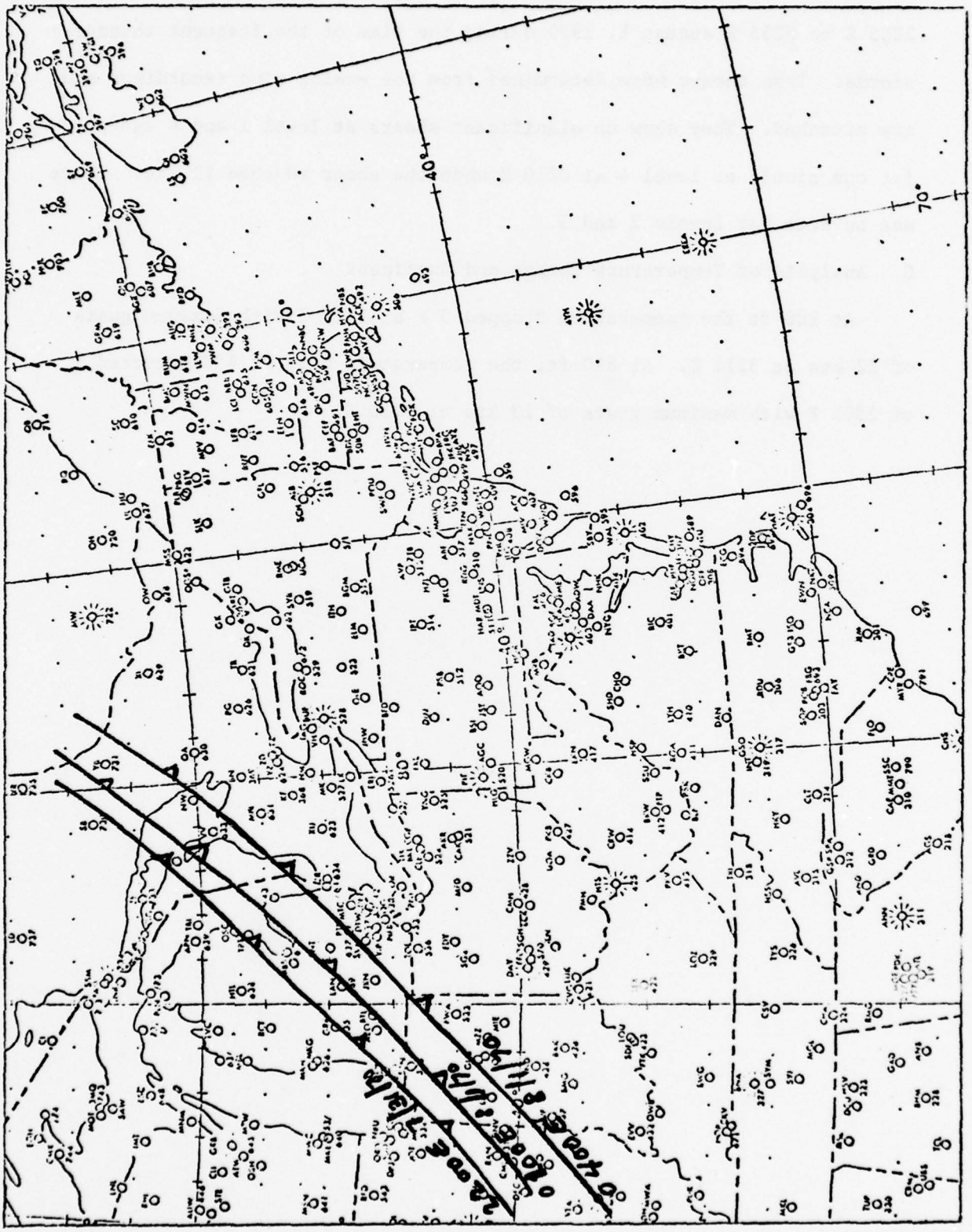
There was no radar data available for this date.

B. Detailed Analysis of Wind Shears

A minute by minute tabulation was made of the wind shear from 2255 E to 0255 E August 1, 1970 during the time of the frequent thunderstorms. Then shears were determined from the analog wind recordings and are attached. They show no significant shears at level 1 and 4 except for one minute at level 4 at 0210 E when the shear reached 11 kts. There was no data for levels 2 and 3.

C. Analysis of Temperature Change and Gustiness

At 100 ft the temperature dropped 5°F at 2310 E with maximum gusts of 22 kts at 3213 E. At 890 ft, the temperature drop of 4°F occurred at 2305 E with maximum gusts of 23 kts at 3210 E.



Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of November 4, 1970

On this date, thunderstorms were reported at all four of the surface weather observing stations in the area during the late afternoon and evening. Wind shears meeting the minimum criteria were observed at shear level 1 (100 ft. - 40 ft.) at approximately the time thunderstorms were in the vicinity. However, shears did not meet the requirement at level 4 (890-570 ft.).

A. General Synoptic Situation

At 1600E of November 4, 1970 there was a well developed northeast cyclone off the east coast of the U.S. The low center of that storm extended westward over south eastern Pennsylvania and Delaware. An occluded front extended from the low eastward off the coast. By 1900E the low center was located just over Philadelphia with a second trough southward from the low just east of New Jersey. By 2200E the low center had moved slowly northeastward by about 50 miles. Philadelphia was well within the circulation of the low pressure area. The occluded front lay across Long Island.

By 0100E of November 5, 1970 the low center was south east of New York City while a second low center had formed just a few miles south west of Philadelphia.

The surface weather observations of November 4, 1970 indicate that thunderstorms with occasionally heavy rain showers began to be reported at 1431 EST at the Philadelphia International Airport. These thunderstorms were generally moving north eastward and continued to be reported until 2210 EST. The North Philadelphia Airport also reported thunderstorms with occasionally moderate rain showers until 2140 EST. Willow Grove NAS reported a similar pattern, thunderstorm beginning at 1455E

and ending by 2258 EST. Reading, Pa. had a short period of thunderstorm activity from 1713 EST until 1740 EST.

During this period of thunderstorm activity, the surface winds at the Philadelphia International Airport were not particularly strong. The maximum wind speed was 16 kts. at 1610E with no particularly significant gustiness. However, the North Philadelphia Airport had surface gusts to 28 kts. at 2105 EST, NAS, Willow Grove, 18 kts. at 1658 and Reading, 30 kts. at 1955 EST. This gustiness corresponded in time closely to the time of the wind shear.

Radar film from Atlantic City, N.J. WSR-57 Radar indicates an area of thunderstorm and heavy rain shower activity over the area. The radar film coverage was available only until 1432 EST of November 4, 1970. This film shows a large echo which extended west and south west of the tower at that time.

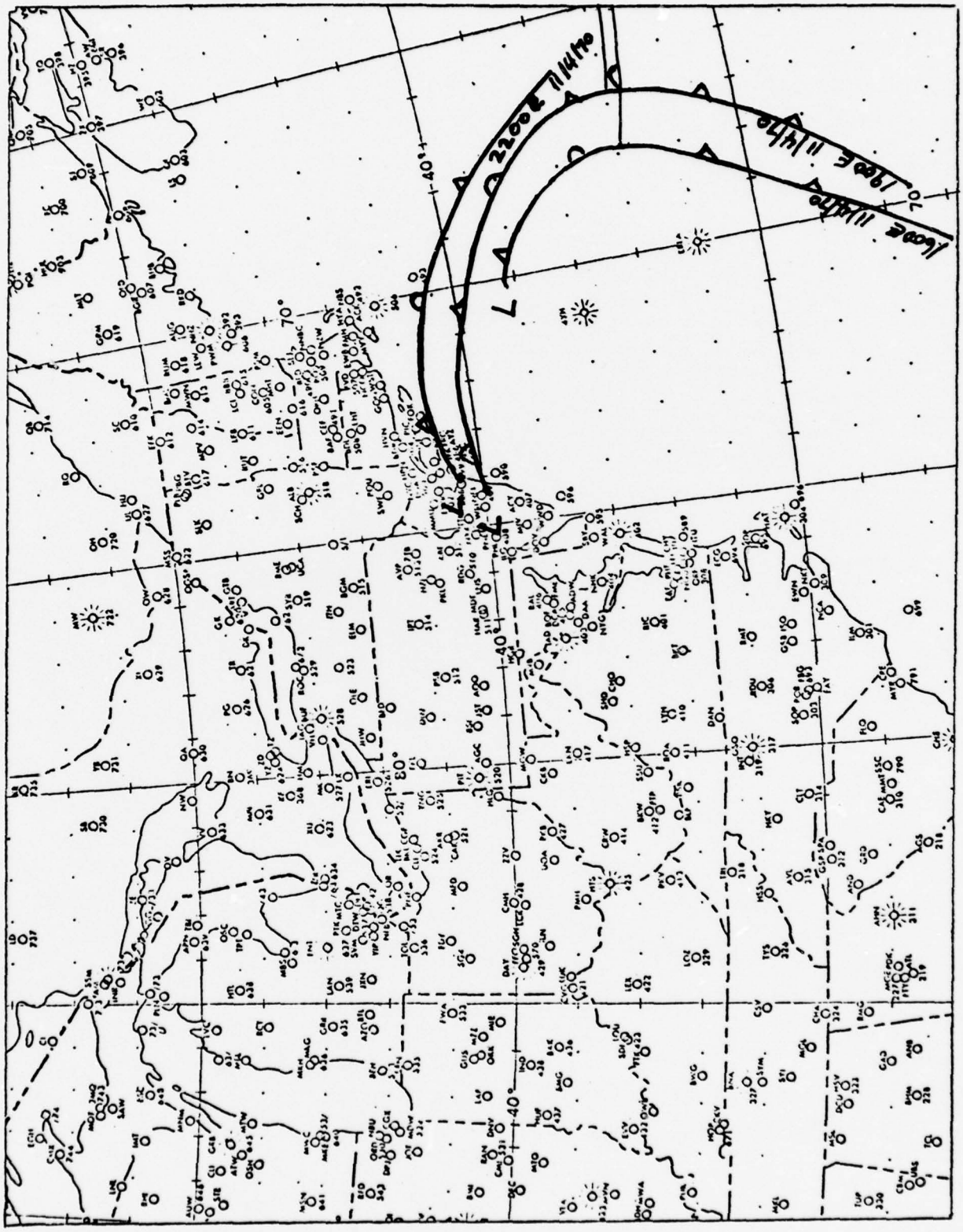
B. *Detailed Analysis of Wind Shears*

The minute by minute tabulation of the wind shears from 2010E to 2155E as determined from the analog record of the Aerovane anemometer is attached. These data show only rare shears meeting the 10 kt. requirement at level 4 (890-570 ft.). These occurred at 2108E and 2123E and 2124E. However, the shears at level 1 (100 ft. - 40 ft.) of six kts. or more were observed almost continuously from 2011E to 2055E and then occasionally until 2133E. In this case, the winds were from the north east until 2104E when they shifted abruptly to the south although at that time the wind speed did not change much.

C. Analysis of Temperature Change and Wind Gustiness

An analysis of the thermograph records and gustiness records for the 100 and 890 ft. elevations revealed the following. At 100 ft. the

thunderstorm temperature drop of 8°F occurred at 2105E while the temperature drop of 6°F occurred at 890 ft. at the same time. During the period between 2120 and 2125 maximum gusts of 23 kts. were observed at 100 ft. while no average wind speeds exceeded 30 kts. At 890 ft., the maximum gust of 38 kts. occurred at 2035E while winds in excess of 30 kts. were recorded from 2050E to 2120E.



Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of December 4, 1964

On this date, the magnitude of the wind shear exceeded the specified criteria on the tower on two separate occasions. The minimum criteria for significant wind shears were as follows: level 1 (40-100 ft.) at least 6 kts., level 2 (100-350 ft.) at least 9 kts., level 3 (350-570 ft.) at least 8 kts., and level 4 (570-890 ft.) at least 10 kts. These shears occurred during the time intervals between 0925 and 1100 EST and again between 1625 and 2210 EST.

A. General Meteorological Situation

At 0700 EST of December 4, 1964 a low pressure center with a frontal wave was centered over south central Kentucky. The lowest pressure was about 1004 ml. A cold front extended southward from the center through western Alabama and then into the Gulf of Mexico east of New Orleans. A stationary front extended generally eastward from the center through south central Delaware and off the New Jersey coast near Cape May. This would place the front about 70 nautical miles south of Philadelphia at that time. Subsequently, the succeeding three hourly synoptic charts show the low center moving north eastward to a position in south western Pennsylvania at 1600 EST at which time the frontal wave began to occlude and by 2200 EST the low center was located on the central portion of the New York - Pennsylvania boundary with the occluded and cold fronts along a line south south westward west of Harrisburg, Pa. (100 miles west of Philadelphia) and thence along the Appalachian mountain. During this time, the stationary front south of Philadelphia had been maintaining a generally NE-SW orientation about 40 miles southeast of Philadelphia between Philadelphia and Atlantic City, New Jersey. By 0100 EST December

5, 1964, the occluded front was still 100 miles west of Philadelphia but the stationary front had moved southward to near Salisbury, Md. This situation caused a generally prevailing north easterly wind of between 5 and 13 kts. at the surface at Philadelphia during the day. This was accompanied by light rain, drizzle and fog with poor visibility during the day at the Philadelphia International Airport. Occasionally the rain increased in intensity to moderate and heavy. Similar conditions prevailed at the North Philadelphia Airport, the U.S.N. Air Station at Willow Grove and at the airport at Reading, Pa. though at those locations, both precipitation and winds were of lighter magnitude.

During this period, not only was a front in the vicinity of the station, but this frontal surface slanted upward and northward to intercept the tower at apparently near the 570 ft. elevation and produced a strong inversion of as much as 2.4°F/100 ft. between the 350 and 570 ft. elevation and up to 3.6F°/100 ft. between the 570 and 840 ft. elevation.

B. Detailed Analysis of Wind Shears

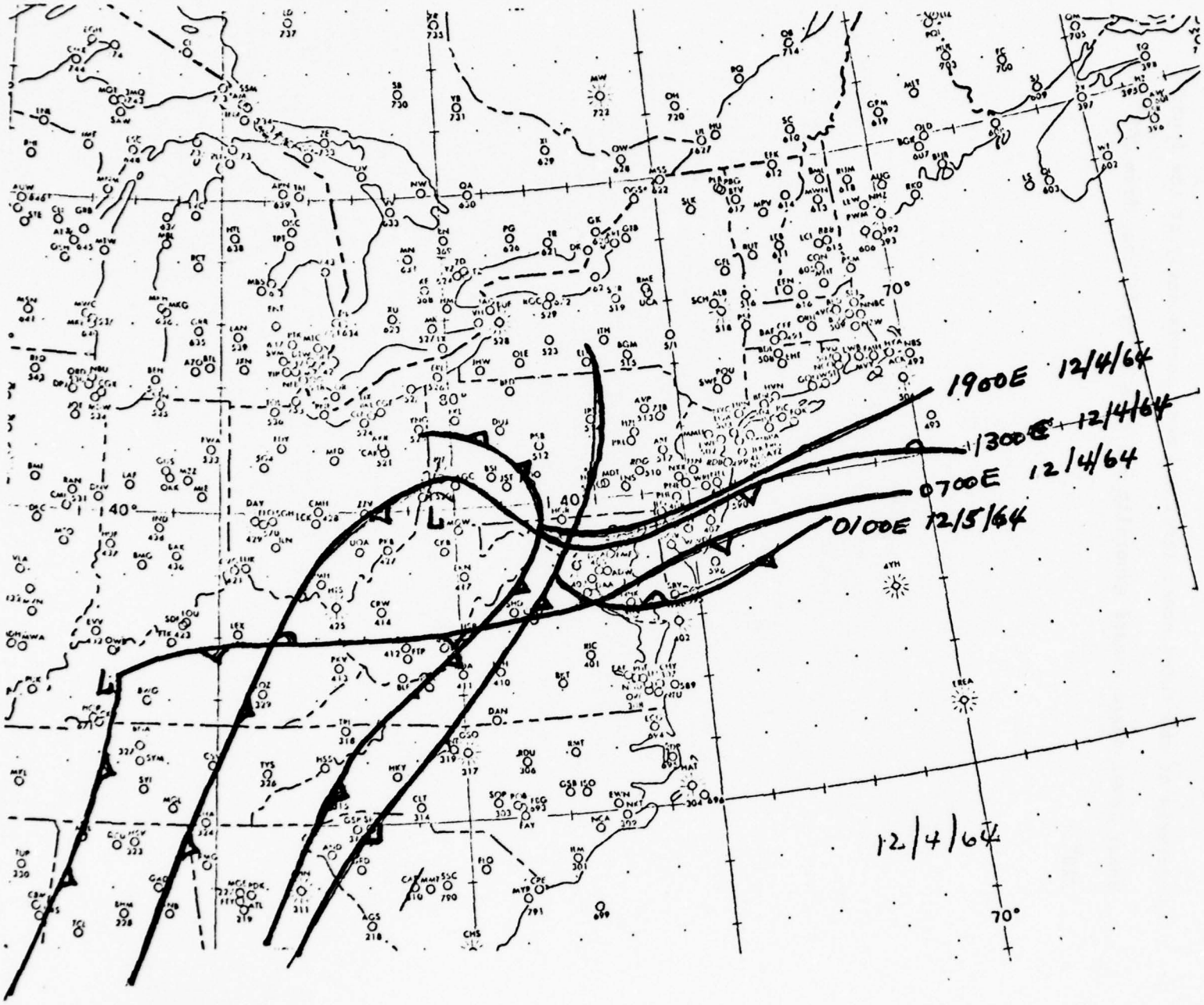
During this time period, no wind data was available on the tower for the 40 ft. elevation as that anemometer had not yet been installed. A minute by minute tabulation was made of the wind direction and speed as determined from the strip chart gust recorders of the Bendix-Friez Aerovane Anemometer for the upper four wind levels. From these wind vectors (speed and direction) the wind shear vector was calculated (magnitude (kts.) and direction (degrees)). Using the convention of upper wind elevation minus the lower wind elevation.

The detailed tabulation of these computations is attached. The data indicate that between 0930 and 1100 EST, the wind at 570 ft. varied between 14 kts. and 27 kts. with direction consistently between 75° and 90-95° while the winds at the 890 ft. elevation were consistently of lower magnitude varying from 27 kts. down to 8 kts. with directions consistently more southerly 100° to 120°. These two wind vectors produced shears that varied in magnitude and direction from as little as 3 kts. to a maximum of 17 kts. with shear direction backing from 160° to 260° toward the end of the period.

At the same time, during this first period from 0930 to 1100 EST, the minimum shear criteria were only occasionally satisfied at the second and third shear elevations.

Between 1000 EST and 1600 EST all levels had generally lower shears with the 4th level occasionally exceeding the minimum of 10 kts. By 1625 EST the wind speeds at the 100 ft. elevation were very light (calm to 5 kts.) and east south easterly and becoming light and northerly by the end of the period of 2210 EST. At 350 ft., the winds were stronger, running from 7 to 10 kts., easterly then diminishing to 4 to 7 kts. north easterly. The 570 ft. winds started at 10-14 kts. from 150° and gradually decreased variably to 2 to 4 kts. to 1940 EST then increased for a period to 2020 to 10 kts. after which the wind was too erratic to evaluate by eye until 2036. After that time, the winds settled down to a more steady 7-10 kts. from about 50 to 70°. The winds at the 890 ft. elevation followed the pattern of the 570 ft. elevation but were persistently from the south 180° to 200°. This was probably due to the frontal surface intercepting the tower at about the 570 ft. elevation with easterly winds below and southerly winds above.

This situation caused wind shears to occasionally exceed the minimum criteria at the third shear level and more persistently at the fourth shear level where shears generally ran from 10 to 16 kts. from 200° to 220°.


1900E 12/4/64
1300E 12/4/64
0700E 12/4/64
0100E 12/5/64
12/4/64
70°
40°

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of February 26-27, 1965

Occasionally, late on the 25th of February and into the 26th, there were times when the shears between 100 ft and 350 ft (shear level 2) exceeded the minimum criterion. However, between 2100 EST and 2230 EST of February 26, the shears at shear level 2 persistently exceeded the minimum criteria until 0100 EST of February 27, 1965. The shears at level 3 (between 350 ft and 570 ft) also persisted greater than minimum. But the shears at level 4 never did exceed 7.6 kt and were generally less than 5 kt.

A. General Meteorological Situation

At 1900 EST of February 26, 1965 there was a large high pressure area over the southeastern Gulf States which extended as a ridge up into the area of Kentucky, Indiana, and Ohio. A warm front extended over a low in Canada west of Lake Superior along the eastern border of North and South Dakota and Nebraska. This front moved eastward to just west of Illinois by 0100 E of February 27, 1965.

The hourly surface waather observations for the Philadelphia International Airport, North Philadelphia Airport, NAS Willow Grove and Reading all show that although there was no frontal passage during the period, the surface winds were from the West and Westnorthwest (270 to 300°) 13 to 18 kt with gusts to 25 kt. The gustiness was stronger at Reading, Pa.

B. Detailed Analyses of Wind Shear

The detailed, minute by minute tabulation of the wind direction and speed for the 100 ft, 350 ft, 570 ft and 890 ft elevations and their corresponding calculated wind shears are attached. These wind directions and speeds were determined by eye from the analog record of the Bendix-Friez Aerovane anemometers installed at those levels on the tower.

The records indicate that at the 100 ft level the wind started at 2155 at 23 kt from 295° and then varied between 18 and 27 kts from the direction 290° to 305° for the rest of the period. The winds at 350 ft although from generally the same direction were less in speed ranging in speed between 7 and 20 kts. This caused the wind shear direction to be opposite that of the upper wind as is the usual case. During this term, the wind speed and direction at the 570 ft and 890 ft elevations were similar to, although somewhat stronger than, the 100 ft winds. As a consequence, strong wind shears exceeding the criterion for shear level 3 were produced but no shears satisfied the criteria of 10 ft for level 4. The directions of the shears at level 3 were more typical, being in the same general direction as the upper wind.

An examination of the analog wind records did not indicate any apparent instrumental malfunction to account for the lesser wind speed at the 350 ft elevation.

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of February 13, 1966

During the morning of February 13, 1966, there were occasional shears of over 9 kts at level 2. By 1130 EST the shears at levels 2 and 4 began to persistently exceed 9 and 10 kts respectively so that by 1255 and until 1509 this was a rather regular occurrence. In addition the shears at level 3 also began to increase exceeding 8 kts by 1512 EST.

A. General Synoptic Situation

At 1000 EST of February 13, 1966 a well developed low pressure center was situated over southwestern Virginia. An occluded front extended east out of the low where it became a cold front in western Virginia and then extended south eastward through eastern North Carolina and off the east U. S. coast. A warm front extended north eastward between Washington D. C. and Richmond, Virginia to off the east coast between Solisburg, MD and Norfolk, VA. This low center moved northeastward toward Philadelphia and by 1600 E it was located near Hagerstown, MD. The cold front by then was still west of Philadelphia and Wilmington, Del. The 1300 EST surface map indicates the warm front which was oriented east-west was still south of Philadelphia but by 1600 EST it had passed north of Philadelphia.

An examination of the hourly surface weather observations for the Philadelphia International Airport, North Philadelphia Airport, NAS Willow Grove, Pa., and Reading, Pa. indicate that rain and fog persisted during the day, the rain increasing in intensity during the morning becoming moderate in mid morning. This pattern was moving SW toward NW.

The warm front apparently passed over and northward of Philadelphia International Airport about 1440 EST. The wind shift occurred at 1959 EST at Reading, at 1615 at North Philadelphia Airport and at about 1640 at NAS Willow Grove. This would indicated the front passed through the tower location after 1620 EST.

In addition, a line of cumulonimbus was observed to the west of Philadelphia International Airport at 1655 EST and thunderstorms were observed at 1735 EST. This all occurred after the period of the wind shears, with no significant shears being recorded from the wind tabulations during the time of the thunderstorm. The strongest shears from the 10 minute wind observations were 15 kts during the interval 1225 to 1340 EST at the 4th level.

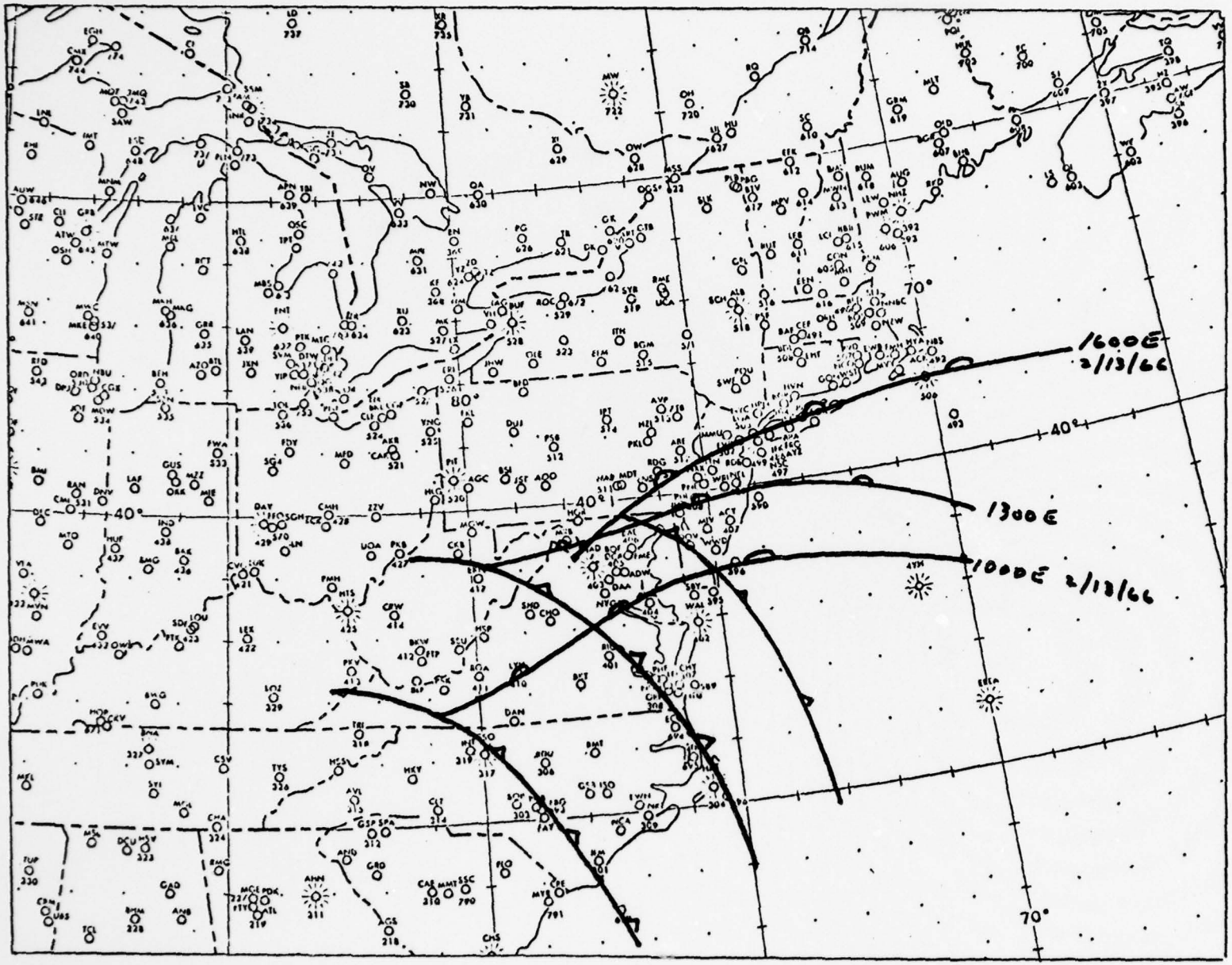
B. Detailed Analysis of Wind Shears

A minute by minute analysis of the wind shears was made by analyzing the strip chart recordings of the Bendix-Friez Aerovane anemometers during the period when significant shears were indicated from 1255 EST to 1525 EST of February 13, 1966. The tabulation of one minute wind shear data is attached.

The wind at 100 ft persisted generally from the east and eastnortheast 75° to 95° gradually veering after 1510 EST to 120° with wind speeds varying from 10 to 16 kt occasionally as low as 5 kt. The pattern at 350 ft was similar to that at 100 ft with wind speeds being between 1.5 and 2 times stronger and the veering starting earlier at about 1420 EST. The wind direction finally reached 145°. A similar pattern was apparent at the 570 ft elevation with faster wind speeds than at 350 ft and the veering starting at 1410 EST and reaching 155° by 1525. At the 890 ft elevation the wind speeds were less than at the 570 ft elevation until 1412 EST after which time the winds speeds were faster than at the 570 ft elevation. The 890 ft wind direction started at 100° to 105° at the beginning of the period and gradually veered to 155° by the end.

The increase of wind speed with elevation between the 100 and 350 ft levels produced shears generally in the same direction as the wind with the magnitude of the shears varying erratically above and below the minimum of 10 kts until toward the end of the period when they became consistently stronger than 10 kts.

On the other hand, the shears between 570 ft and 890 ft when above lo kts were from 215-230° at the beginning of the period and then later after 1447E the shears were in the same general direction as the wind.


1600E 2/13/66
1300E
1000E 2/13/66
80°
70°
40°

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of November 2, 1968

In this case, shears meeting the minimum criteria began occurring intermittently by 2310 EST of November 1, 1968 at the third shear level. The shears became more persistent by 2340 EST and then lasted until 0710 EST of November 2, 1968. These were all prefrontal to a cold front which was approaching from the northwest.

A. General Synoptic Situation

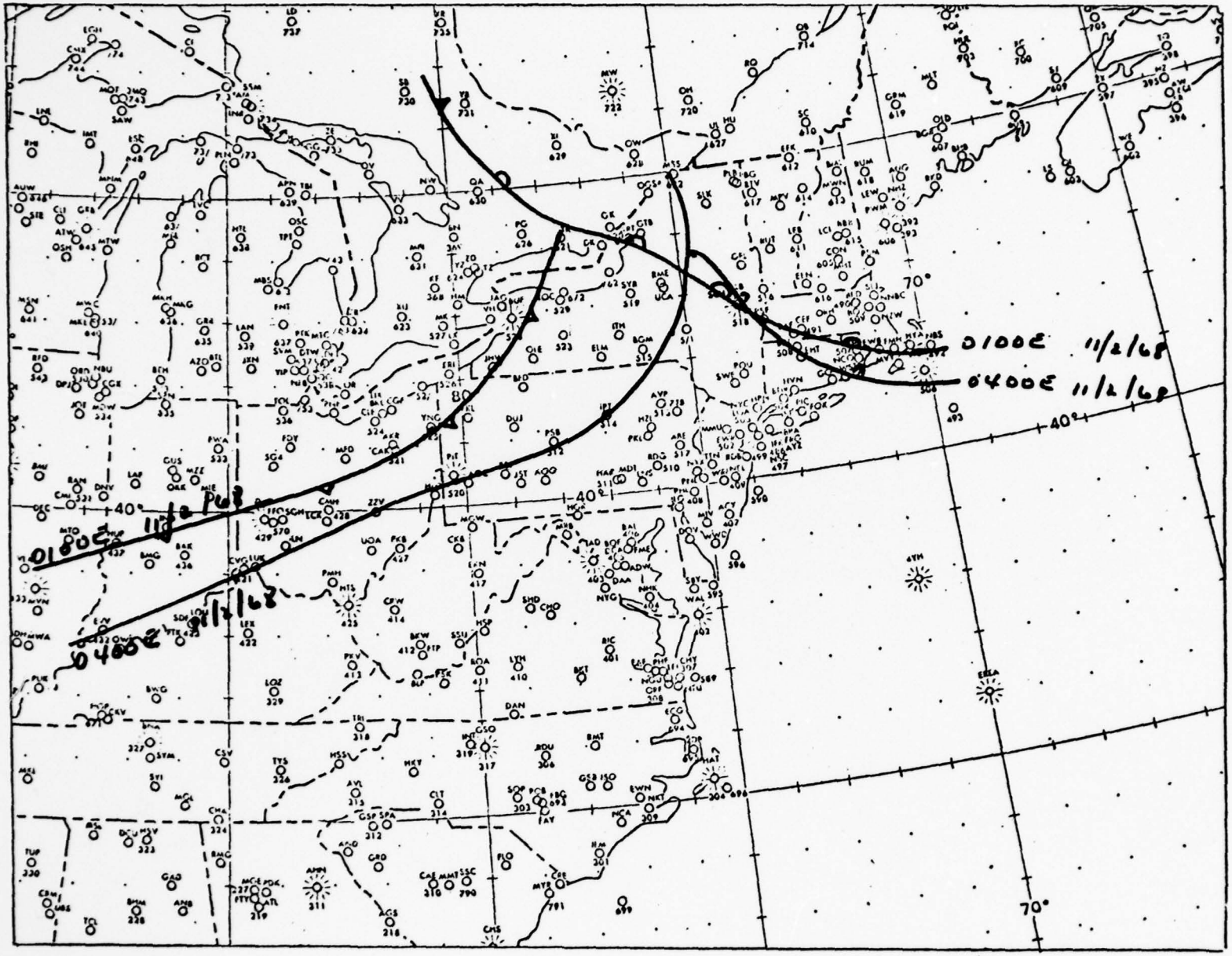
A cold front which was oriented northeast-southwest in Indiana and Ohio had moved into northwestern Pennsylvania by 0100 EST, November 2, 1968. This front was preceeded by a week trough of low pressure about 200 miles from the front. This trough passed over Philadelphia at about 0400 EST. The wind field was generally southwesterly until the wind veered with the approach of the front. The actual fontal passage occurred at about 1900 EST, about twelve hours after the significant shears had stopped.

At 0710 EST, the time of the last shears, the front was still about 120 miles northwest of Philadelphia. During the time of the shears, the surface winds were from the southwest (240°-260°) seven to nine knots.

B. Detailed Analysis of Wind Shears

The minute by minute analyses of wind shears determined from the Aerovane Anemometer wind records for the period 0210 EST to 0710 EST, November 2, 1968 are attached. The winds at the 40 ft elevation were calm during the entire period. At 100 ft, the winds were light and from 230° gradually veering to 300° and then backing to 230°-245°. At the upper levels, the winds veered with height while generally increasing in speed.

Shears meeting the minimum criteria occurred consistently at the third level (350-570 ft) and intermittently at the second level (100-350 ft). The shears of largest magnitude were 15 to 16 kts at about 0700 EST.


0100Z 11/2/68
0400Z 11/2/68
0100Z 11/2/68
0400Z 11/2/68
70°
40°
80

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of November 12, 1968

On this date, the magnitude of wind shears exceeded the minumum requirement at only level 2 (100-350 ft) as determined from the ten minute integrated wind vectors. This occurred during two separate intervals 0125 to 0410 EST and 1010 to 1410 EST of November 12, 1968. However, the one minute evaluation indicated that shears exceeding the minimum requirements also occurred sporadically at levels 3 (350-570 ft) and 4 (570-890 ft).

A. General Synoptic Situation

At 0100 E, November 12, 1968, the low pressure center of a typical Northeastern which had moved northeastward up the east coast of the U. S. was located about 200 miles east of Maine. The cold front associated with this center lay 300 miles or more off the coast. This low pressure center had passed about 200 miles east of Philadelphia at about 1500 E November 10, 1968. Until 1600 E, November 12, 1968, the low pressure center had continued slowly northeastward and a ridge of high pressure covered the middle Altantic states during that time.

The surface winds had been light and variable gradually shifting to light northerly by 0700 E and finally northwesterly by 1300 E. A cloud cover of stratoculumus clouds partly covered the sky.

B. Detailed Analysis of Wind Shears

A minute by minute analysis of wind shears during the two periods of November 12, 1968; 0125 to 0410 and 1010 to 410 EST was determined from the analog records of the Aerovane Anemometers. This tabulation is attached. There had been occasional shear meeting the criteria at various levels starting at 2255 EST of November 11 and continuing until 0110 EST of November 14, 1968. However, the largest and most persistent shears occurred during the periods of this case.

The shears meeting the minimum criteria first appeared at level 2 at 0126 EST. They then spread upward to level 3 by 0226 EST while becoming stronger at level 2. A shear of 17.1 kts was recorded at level 2 at 0230 EST.

The shears at level 3 then began to diminish in magnitude while at the same time increasing at level 4 when the criteria for that level was reached at 0242 EST. The shears then continued sporadically until 0410 with the weakest at level 3.

From 1010 EST until 1410 strong shears occurred intermittently at all levels. These shears fluctuated widely in magnitude at all levels, but were most persistent and strongest at level 2 where they reached a value of 23.4 kts at 1215 EST. This is the largest one minute shear that was observed.

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of January 31, 1969

On this date a cold front and warm front passed over the Philadelphia area. Wind shears were meeting or exceeding the minimum requirements and were observed at all four shear levels during the period 0010 to 0640 E.

A. General Synoptic Situation

At 2200 E, January 30, 1969 an extensive cold front lay along a line from Syracuse, N. Y., just west of Pittsburg, Pa., southwestward through eastern Kentucky and Tennessee. A warm front looped southward from the cold front through central Pennsylvania to just north of Washington, D. C., and then eastnortheastward off the New Jersey coast. The cold front moved eastward and the warm front northward. The warm front passed north of Philadelphia after 0100E and the cold front east of Philadelphia by 0530 E.

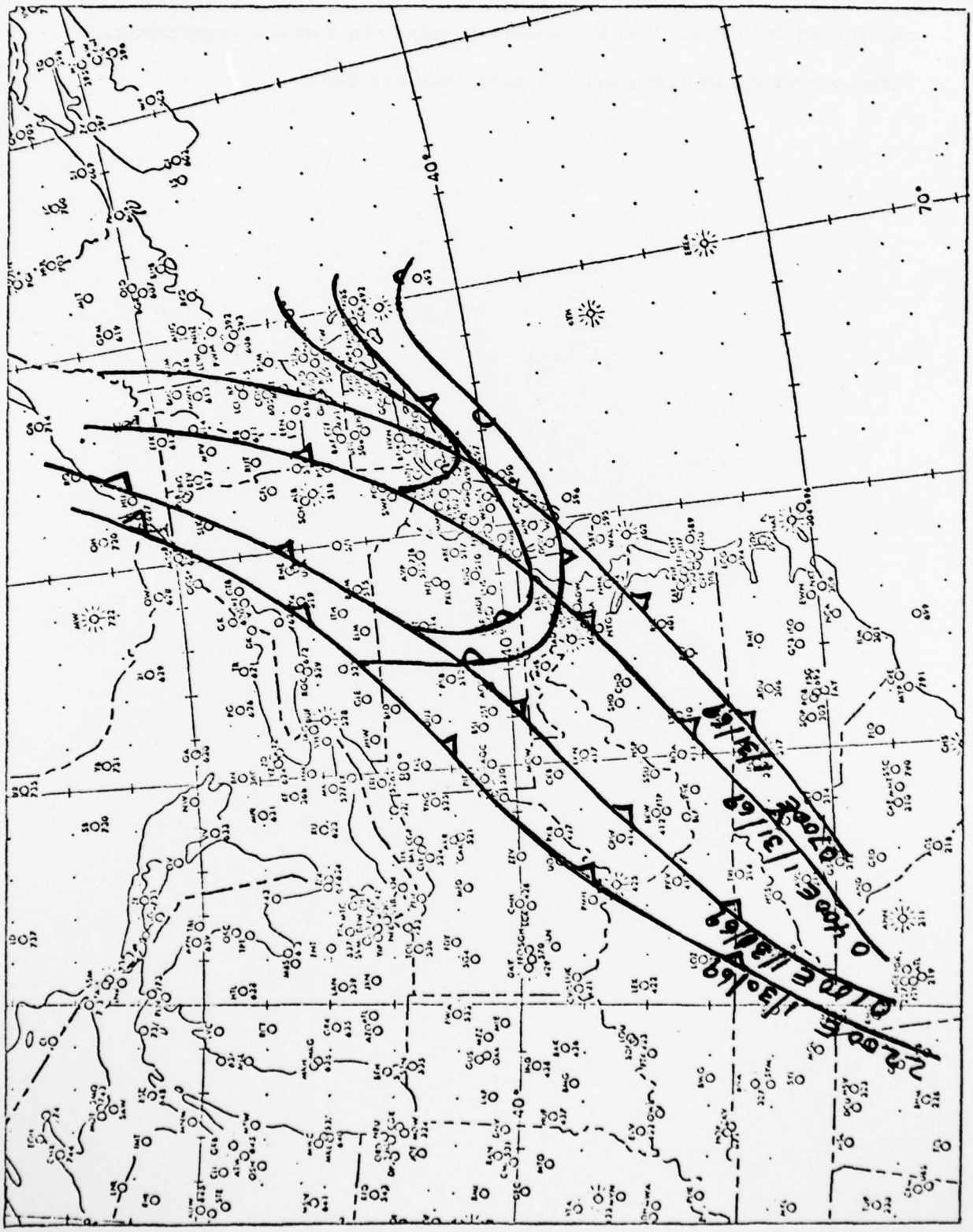
Prior to the warm frontal passage, the winds at the Philadelphia International Airport were NE 3 kts. At 0155 E the wind shifted to 200° at 4 kts gradually reaching 250° at 8 kts by 0455 E. The cold frontal shift to 280° at 7 kts occurred at 0531 E. Until the cold frontal passage the visibility was 1/8th mile then slowly improving to 3 miles by 0455 E and becoming unrestricted at 0531 E. Surface winds became gusty at 0755 E with pressure rising rapidly.

North Philadelphia Airport, NAS Willow Grove and Reading, Pa. all had similar sequences of weather with the timing related to the frontal passages at those locations.

B. Detailed Analysis of Wind Shears

A minute by minute tabulation of the wind shear values for all four levels was prepared from the Analog aerovane anemometer recordings. These

tabulations are attached. They indicate intermittent occurrences of shears meeting the criteria at all of the levels at some time during the period 0010 E to 0640 E. Shears meeting the minimum requirements often occurred simultaneously at more than one level



Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of November 23, 1969

In this case shears met the criteria at levels 2 and 3 during the period 0125 E to 0224 E but not at levels 1 or 4. During this time, the flow over southeastern Pennsylvania was precold frontal southwesterly flow around the western side of a high pressure area.

A. General Synoptic Situation

At 0100 E November 23, 1969, a cold front oriented NE-SW was situated across eastern Lake Huron, south central Michigan and northern Illinois. A large anticyclone was centered east of Cape Hatteras. Philadelphia was in the southwesterly flow ahead of the cold front. By 0400 E, the cold front had moved south eastward about 40 miles and the anticyclone remained essentially stationary.

During this period, the sky was broken with high cirius clouds. Visibility aas unrestricted and the surface winds were southwesterly 7 kts or less at the Philadelphia International Airport and less than that at the other stations.

B. Detailed Analysis of Wind Shear

The minute by minute tabulation of the wind shears at levels 1, 2, 3 and 4 are attached. These were determined by a visual analysis of the analog wind records at all of the levels.

None of the shears at level 1 or level 4 met the specified minimum criteria of 6 and 10 kts. However, levels 3 and 3 had shears that exceeded the minima of 9 kts and 8 kts most of the time. The maximum shear at level 2 was 11 kts while level 3 had 12 kts at 0140 E.

AD-A065 481 DREXEL UNIV PHILADELPHIA PA DEPT OF PHYSICS AND ATMOS--ETC F/G 4/2
DREXEL TOWER DATA ANALYSIS FOR WIND SHEAR,(U)
SEP 78 H NEWSTEIN

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FAA-RD-78-136 NL

2 OF 2
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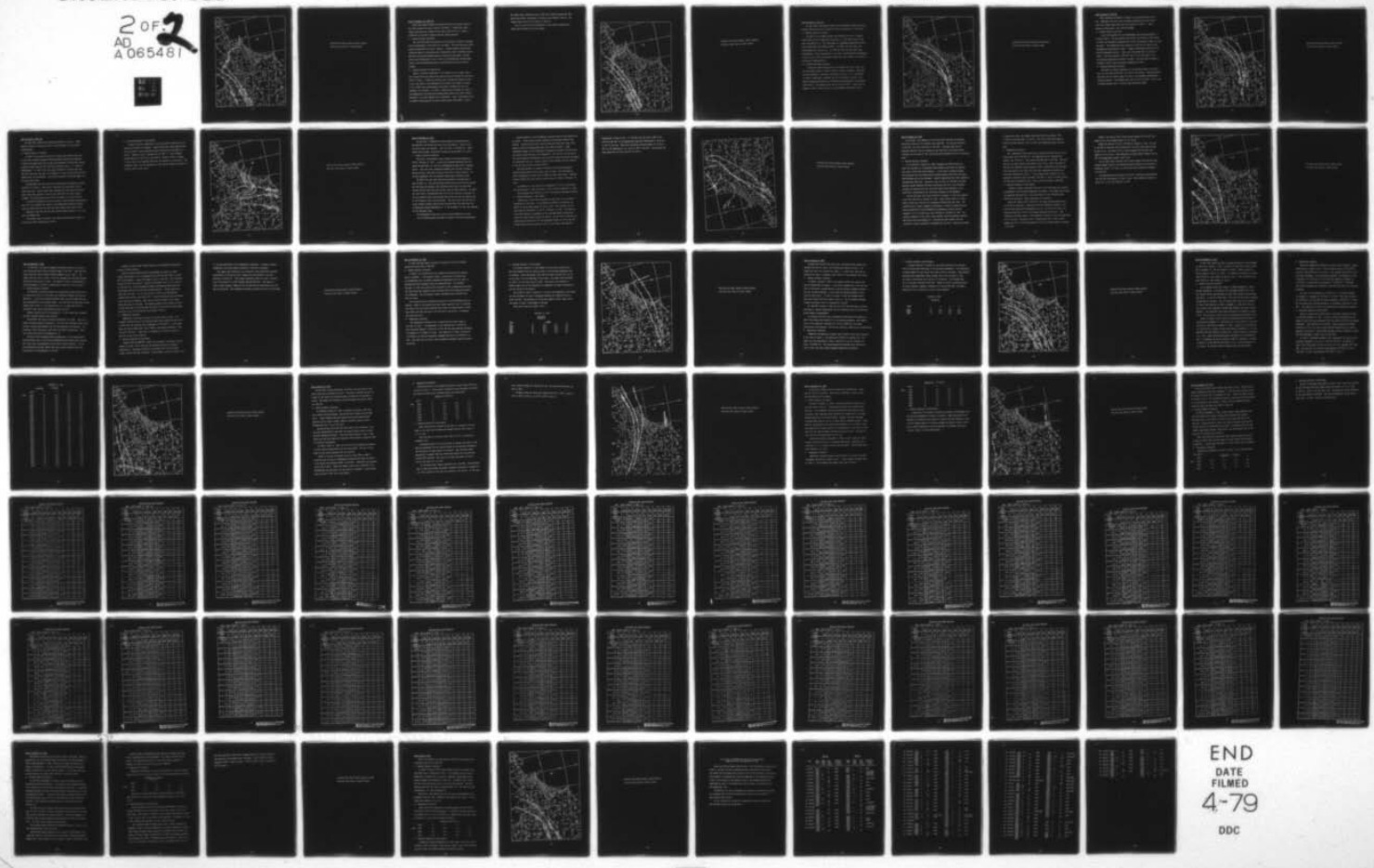

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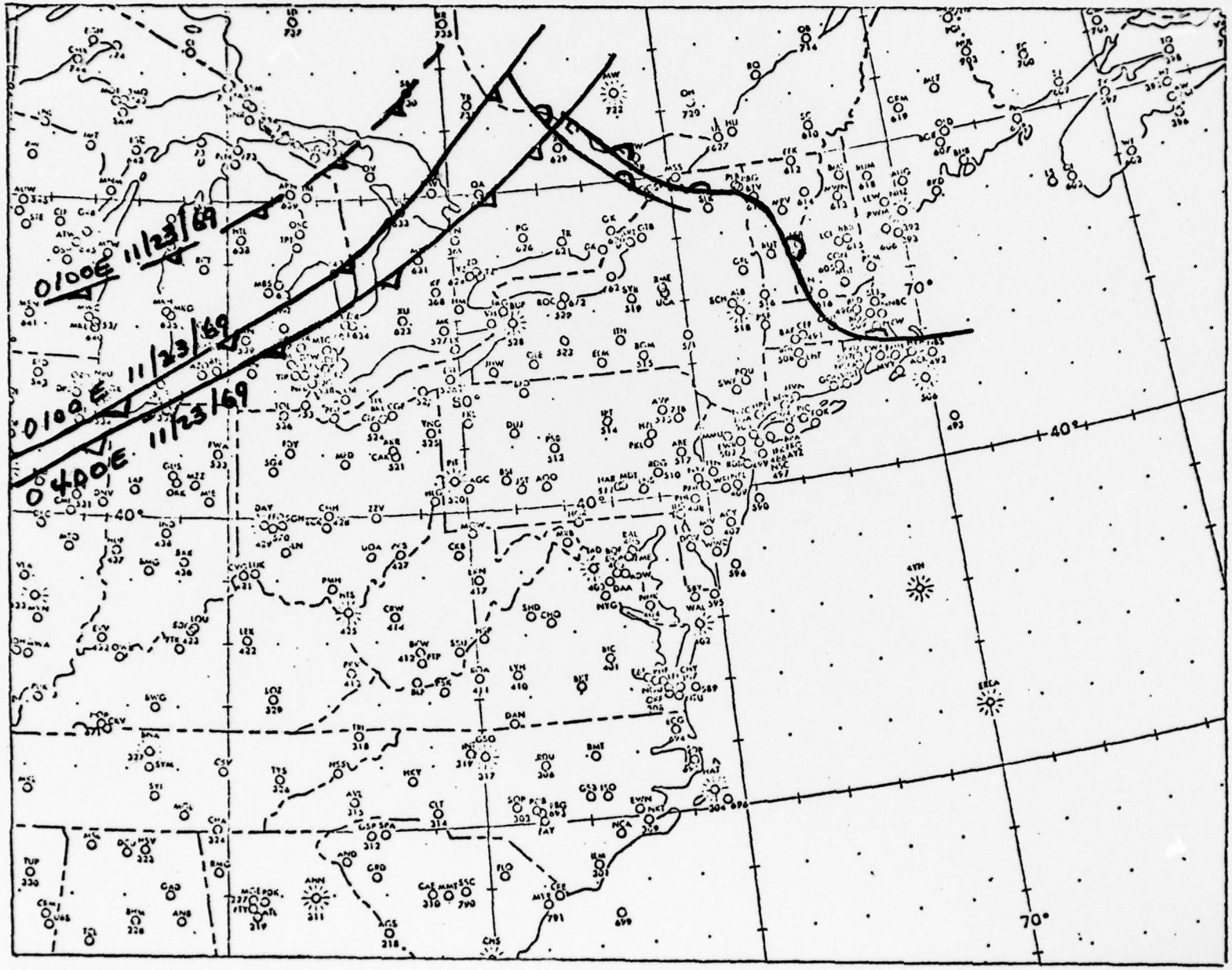

0100E 11/23/69
0100E 11/23/69
0400E 11/23/69
70°
50°
40°
40°
70°

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of November 23, 1969 (B)

There were shears meeting the minimum criteria at various levels on the tower between the hours of 0640 E and 0924 E. During this time, a large anticyclone was located off the east coast of the U. S. while a coldfront was located in Indiana and Ohio moving eastward.

A. General Synoptic Situation

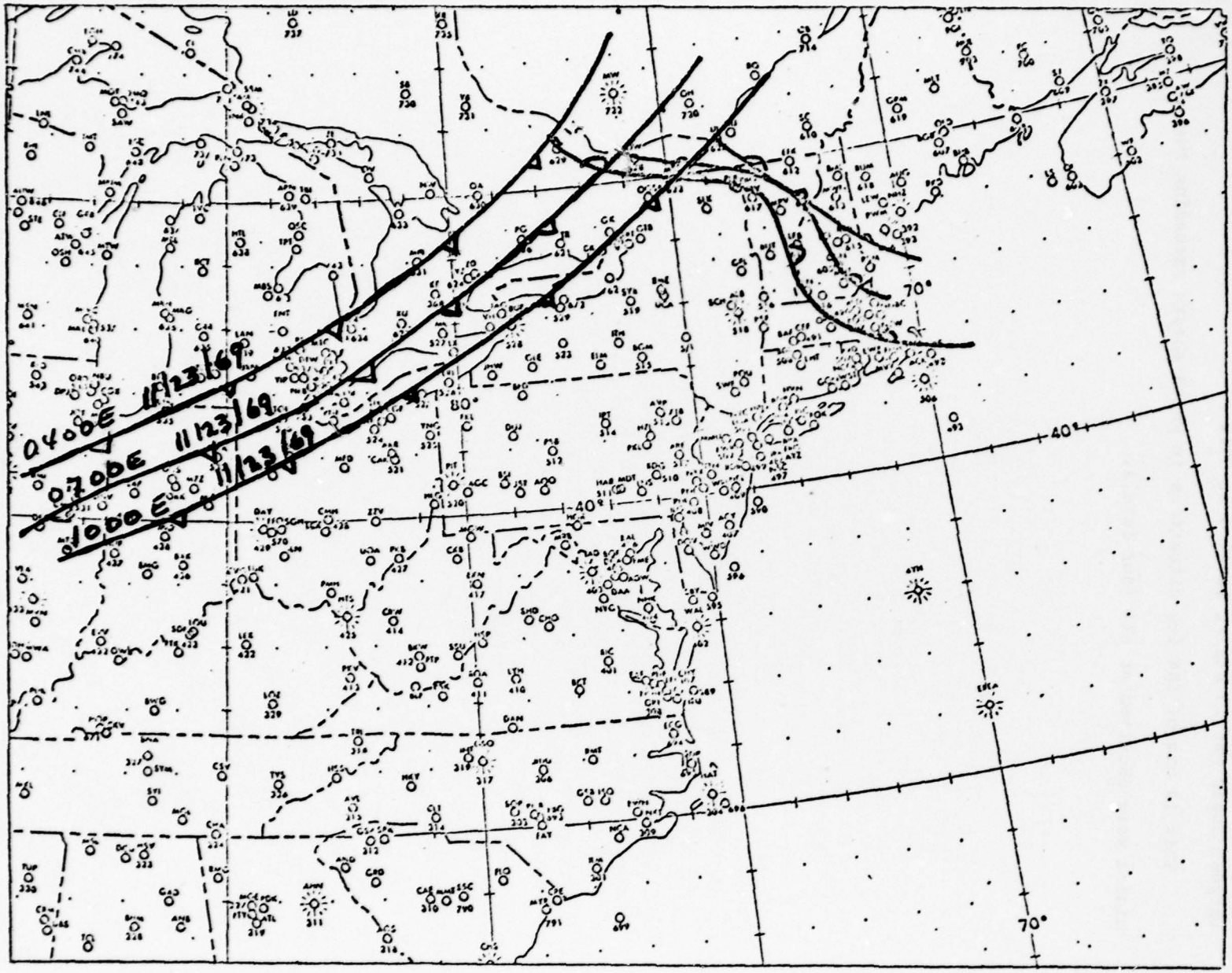
The cold front which was located in the vicinity of Detroit, Michigan moved southeastward to near Erie, Pa. by 1000 E. The wind flow over southeastern Pennsylvania was south westerly. Surface weather observations indicated layers of altocumulus and cirrostratus clouds; visibility which had been unrestricted became reduced in ground fog and smoke. Surface winds were southwesterly 9 kts or less at the Philadelphia International Airport, North Philadelphia Airport, and NAS Willow Grove and calm at Reading.

B. Detailed Analysis of Wind Shears

Minute by minute tabulations of the shears at all 4 shear levels were prepared from the analog wind records and are attached for the period 0640 E to 0924 E. These data indicate that although the shears at level 1 were very small at the beginning of the period, they began to exceed 6 kts at 0859 E and intermittently continued to exceed 6 kts for the remainder of the period. At level 2, shears were in excess of 11 kts at the beginning of the period and remaind mostly above 9 kts until 07555 E. Thereafter, 9 kts was reached only occasionally. Level 3 had shears 8 kts or greater intermittently the whole period except after 0851E. Level 4

had shears which reached 10 kts at 0700 E for several minutes and then again after 0835 E continuing to the end of the period of record. The largest shear was 15 kts at level 4 at 0912 E.

This is one of the few situations in which shears exceeding the minima were observed at all four levels.


0400E 11/23/69
0700E 11/23/69
1000E 11/23/69
80°
70°
40°
70°

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of March 8, 1970 (A)

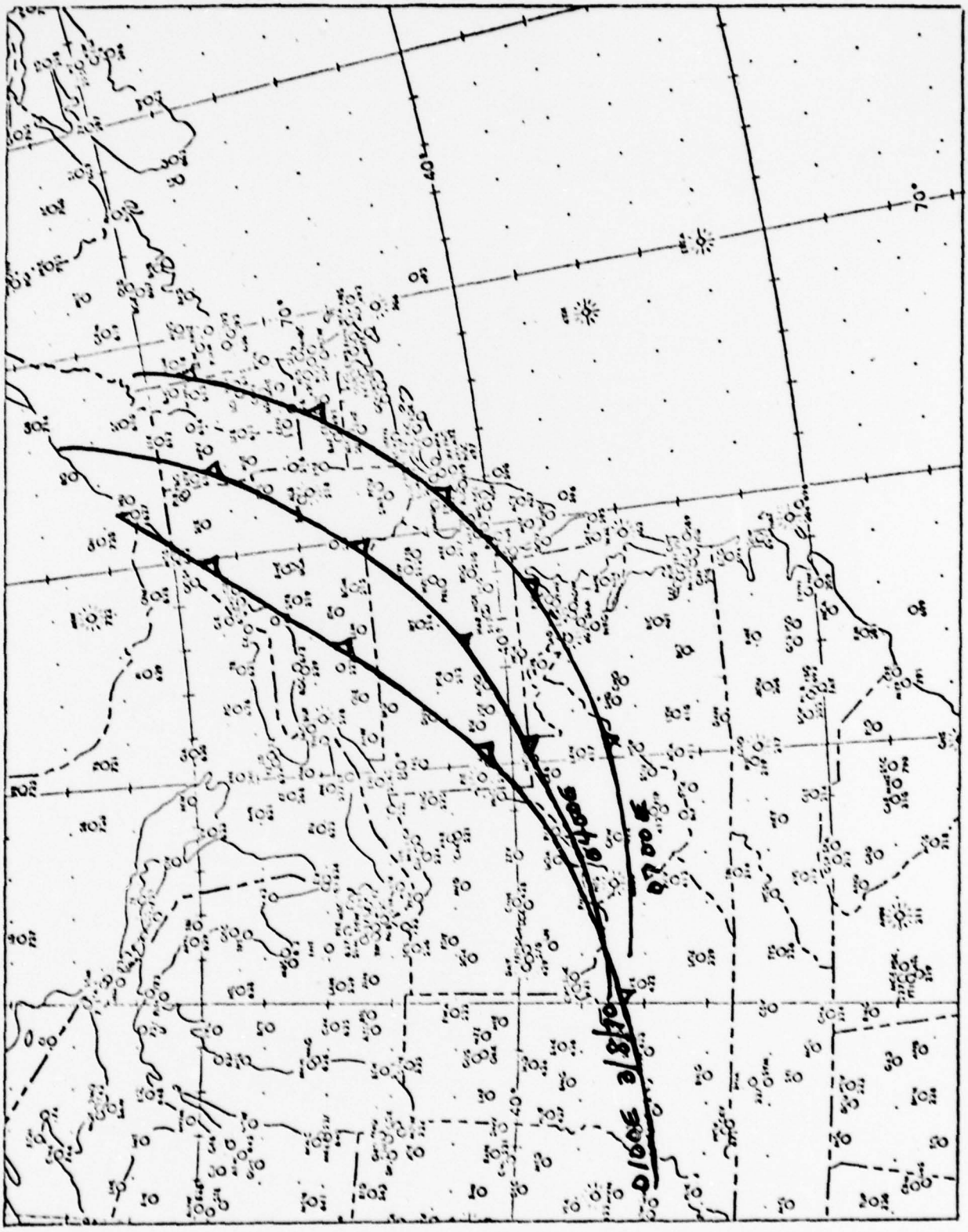
On this date, wind shears greater than the minimum required occurred between 0340 and 0610 E in connection with the approach of a cold front.

A. General Synoptic Situation

At 0100 E a low pressure center was located over the St. Lawrence River Valley north of upper New York State. A cold front from the low, east of Syracuse, N. Y. and Pittsburgh, Pa. extended southwestward along the southern Ohio and Indiana borders. By 0400 E the cold front had moved eastward to Altoona, Pa. At 0750 the front was just about upon Philadelphia. With the approach of the front, the winds were southwesterly 10 kts or less at all four weather stations in the vicinity of the tower. There was no precipitation.

B. Detailed Wind Shear Analysis

A minute by minute tabulation of wind shears for level 1 and 4 for the time period 0340 E to 0610 E, March 8, 1970 is attached. There was no data available to determine the shears at level 2 or 3. The shears at level 4 consistently exceeded the 10 kt criterian for most of the period starting sporadically at 0343 E and then becoming more intermittent after 0440 E. The maximum shear was 16.7 kts at 0425 E. There were no shears at level 1 that met the 6 kt requirements during this period.



Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of March 8, 1970 (B)

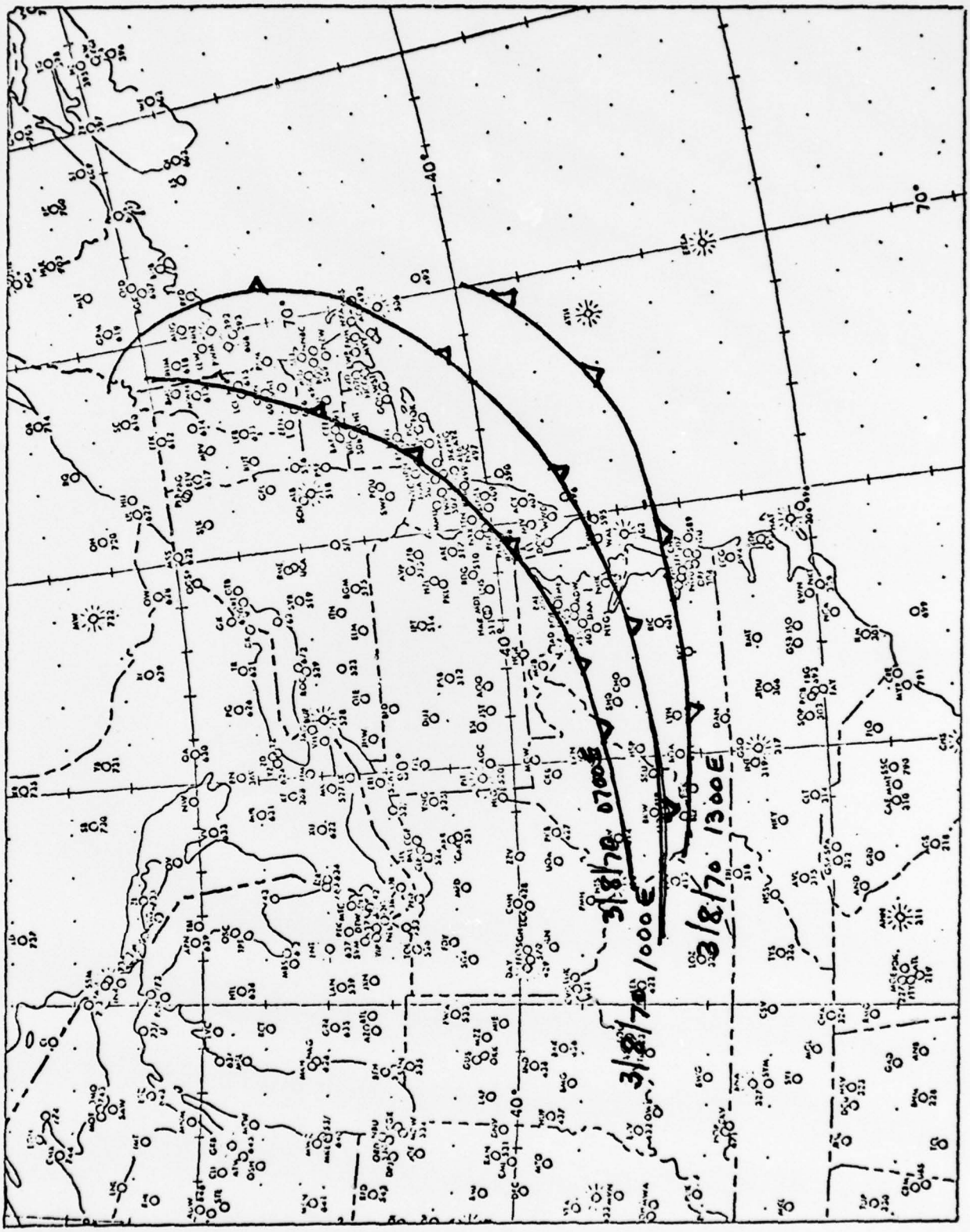
There had been occurrences of shears at one level earlier in the day. Beginning with 1011 E and occurring intermittently until 1210 E there were shears again which met the criteria for level 1. These shears occurred after a cold frontal passage.

A. General Synoptic Situation

A cold front passed over the Philadelphia area moving southeastw d at about 0700 E. The wind shifted from 220°-9 kts at 0655 to 270°-10 kts at 0755 E and thereafter remained 280° to 300° increasing in speed to 20 kts and gusty. The maximum gust was reported to be 36 kts at 1055 E at the Philadelphia International Airport. Similar conditions prevailed at the North Philadelphia Airport. There, the wind became 290° at 12 kts at 0750 E. The wind shifted to 300°-310° up to 24 kts with gusts to 35. The gustiness persisted from 0950 to 1650°E. The wind shift occurred at Reading at 0355 E and the gustiness commenced at 0755 E.

B. Detailed Wind Shear Analysis

The minute by minute tabulaioon of the wind and shears for levels 1 and 4 for the time period 1010 E to 1210 E is attached. These tabulations show that the 6 kt shear values for level 1 was exceeded intermittently during the period. The maximum shear was 12.1 kts at 1109 E. Level 4 had no shears greater than 7.3 kts any time during the period.


3/8/70 0700E
3/8/70 1000E
3/8/70 1300E

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of April 2, 1970 (A)

On this date, shears were observed from 0840 E to 1025 E. These shears occurred in conjunction with a frontal system in the area and thunderstorms.

A. General Synoptic Situation

At 0700 E a low pressure center was located over western Lake Erie. A cold front extended southward through eastern Kentucky and Tennessee. A warm front lopped from the low east and southeast of Pittsburgh, through northern Virginia and off the coast near Atlantic City, N. J., south of Philadelphia. By 1000 E, the low center had moved to central Lake Erie. The cold front was just west of Pittsburgh, Pa. and the warm front had just passed north of Piiladelphia. The fronts continued in the same manner for the next three hours.

Thunderstorms had been reported at Philadelphia International Airport from 0447 E to 0502 E. After that, visibility was restricted in rain, drizzle and fog. Surface winds were northeasterly less than 10 kts until 0955 E when they reached 11 kts from the south after the warm frontal passage. The winds became south 20 kts with gusts to 27 kts by 1022 E.

The North Philadelphia Airport reported no early morning thunderstorms. The rest of the weather was similar to Philadelphia International Airport exept the warm front did not pass over that station until after 1050 E.

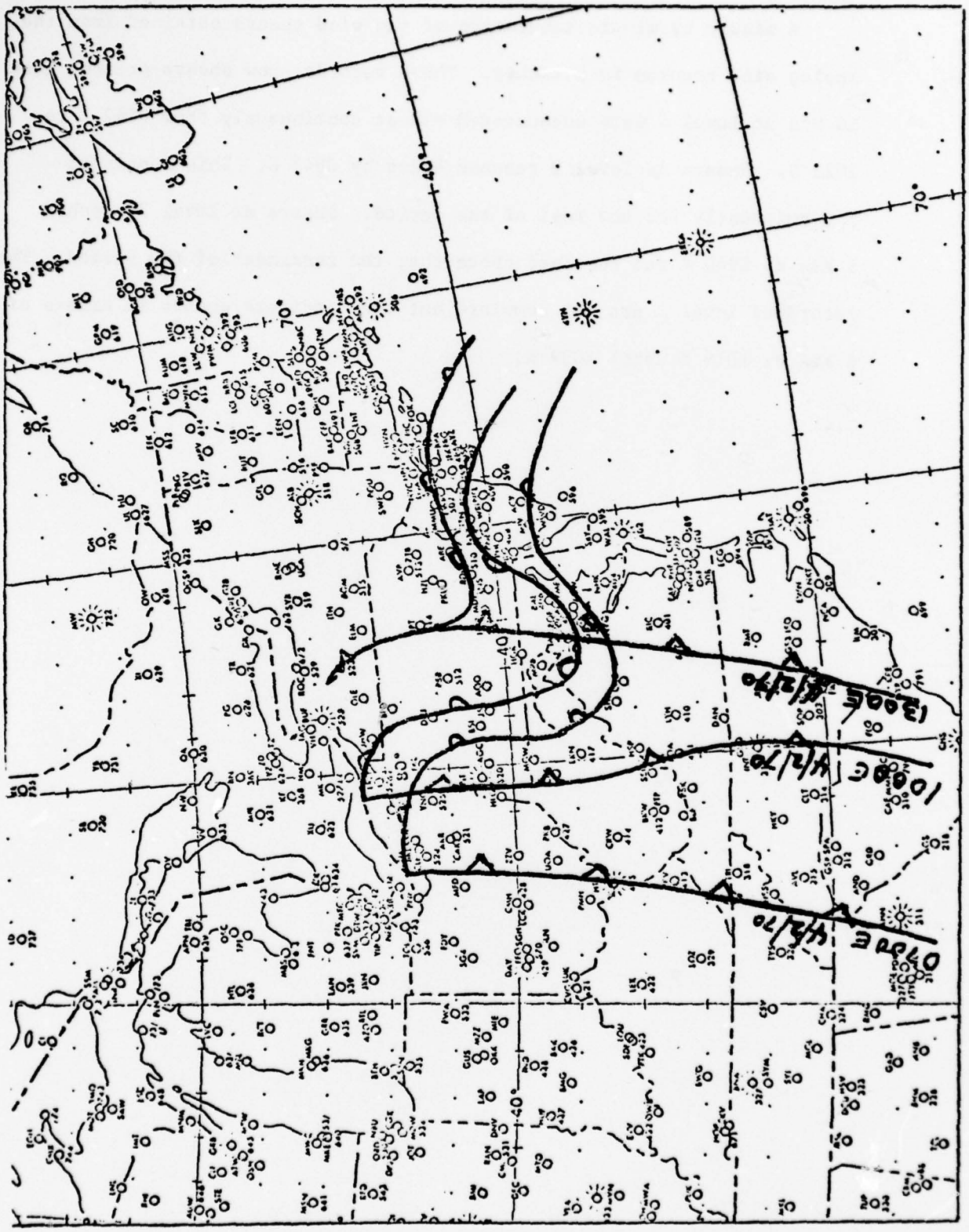
Reading Pa. had rain and fog with surface winds northerly, 6 to 7 kts and no thunderstorms.

The weather radar at Atlantic City showed scattered small echoes in the area at 0713 E lasting until 1033 E.

330

B. Detailed Analysis of Wind Shears

A minute by minute tabulation of the wind shears obtained from the analog wind records is attached. These records show shears greater than 10 kts at level 4 were encountered almost continuously from 0842 E to 1022 E. Shears at level 3 reached 8 kts by 0847 E. This continued intermittently for the rest of the period. Shears at level 2 reached 9 kts at 0940 E and remained above that the remainder of the period. The records at level 1 are not complete but they indicate shears in excess of 6 kts by 1018 E until 1039 E.


1300E 4/1/76
1000E 4/1/76
0700E 4/1/76

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of February 13, 1971

On this date a complicated frontal system was approaching the Philadelphia area during the time of the wind shears. Data for only one shear level was available. This was level 4 (570-890 ft). These shears lasted almost continuously during the period 0010 E to 1125 E.

A. General Synoptic Situation

There was a low pressure center located in central Tennessee at 2200 E, February 12, 1971. A cold front extended northward from the center through Erie, Pa. and then northeastward along the St. Lawrence Valley. This cold front continued southward into the Gulf of Mexico. There was also a warm front from the low south of South Carolina. As the day progressed, the low pressure center moved eastward slowly.

By 0400 E the cold front had moved eastward in Pennsylvania to past Altoona, Pa. The cold and warm fronts south of the low had occluded and lay along the Georgia, South Carolina border with the warm front through central South Carolina and the coast of North Carolina. By 1000 E the cold front in Pennsylvania was still in the vicinity of Altoona, Pa. The low pressure center had intensified and was now over the western part of the Virginia, North Carolina border. The cold front from the low lay south eastward through central North Carolina while the warm front ran northeastward between Washington, D. C. and Richmond, Va. and then eastward off the Maryland coast.

The Philadelphia area lay in the cool pre-warmfrontal air flow.

This occluding system continued to intensity and move northeastward.

Surface weather in the Philadelphia area was typically pre-warmfrontal in return. Clouds became overcast during the preceeding afternoon and lowered. Visibility was better than 10 miles and winds were light south easterly except at Reading where they were light northerly. Light rainshowers began at the Philadelphia International Airport by 0244 E with the surface winds shifting to northeasterly. For the rest of the period the winds remained northeasterly less than 10 kts while visibility decreased in rainshowers and fog. Pressure began to fall rapidly with the approach of the low and frontal systems by 085 EE.

The same sequence of weather occurred at the North Philadelphia Airport and NAS Willow Grove except later in time. The rain bagan at North Philadelphia at 0655 E and at 0630 E at NAS Willow Grove. Pressure falling rapidly was first noted at Willow Grove at 0358 E on February 13, 1971.

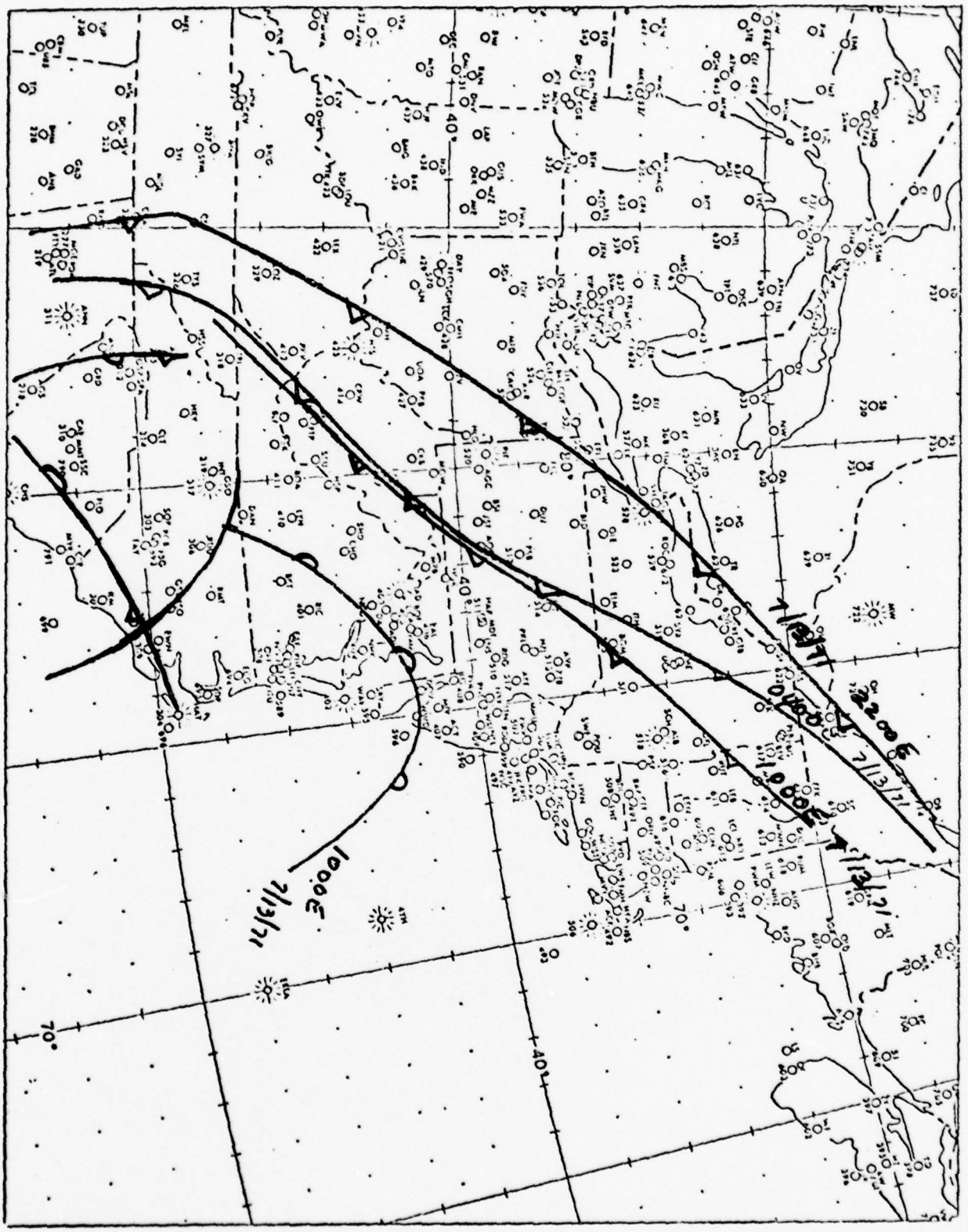
At Reading, Pa. the winds were northeasterly 10 kts or less during the entire period. Light rain began to fall at 0030 E February 13, 1971.

No wind gusts were reported at any of the weather observing stations.

B. Detailed Analysis of Wind Shears

Analog wind records were available for only the 570 ft and 890 ft elevations at this time. It was therefore possible to determine the minute by minute wind shears for level 4 only. This was done for the time interval from 0010 E to 1125 E., February 13, 1971. The shears at that level equaled or exceeded the 10 kt minimum almost continuously except for brief periods during the period. At the 570 ft elevation the wind direction started at 175° and gradually backed to 115° by the end of the period with wind speeds of 20 to 23 kts slowly and regularly

diminishing to about 15 kts. At the same time the wind at 890 ft was 30-32 kts and 185° at the beginning backing and diminishing to 20-22 kts at 140° by the end. These wind conditions produced shears of 10 kts at 205° at the beginning to 7 to 9 kts at 180° at the end. The greatest one month shear was 18.3 kts from 164° at 0731 E.


40°
70°
1200E 7/13/71
1200E 7/13/71
1200E 7/14/71

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of January 22, 1965

On this date, the magnitude of the wind shears exceeded the minimum specified criteria on two separate time intervals. One occurred from 0155 to 0340 EST, the other from 0455 to 1010 EST. Although these are two separate intervals they are grouped as one case since the meteorological situation was the same for both and the interval between the two is relatively short.

A. General Synoptic Situation

On the 0100 EST, January 22, 1965, southeastern United States was under the influence of an extensive high pressure area which was centered just east of North and South Carolina. A cold front in Canada extended south westward into the United States through western Lake Huron and upper Lake Michigan and on into Nebraska. Eastern Pennsylvania was under generally southwesterly wind flow. During the next 12 hours, by 1300 EST, the high pressure system remained relatively stationary with only a four millibar decrease in pressure while the cold front moved south eastward to just reach Erie, Pennsylvania about 300 miles northwest of Philadelphia.

The sky had been clear since 0455 EST of January 21, 1965 and remained clear until 0955 EST on January 22, 1965. Then several layers of clouds began to move into the area of southeastern Pennsylvania and lower. The visibility was 7 miles, gradually decreasing to 3 miles on Ground Fog and Smoke by 0655 EST at the Philadelphia International Airport and then remained 2 1/2 to 3 miles until late afternoon of January 22, 1965. The weather conditions at the other three stations, North Philadelphia Airport, NAS Willow Grove and Reading, Pa., followed the same pattern with the exception of better visibility at Reading than the rest. During the morning

of January 22, 1965, the surface winds were from the southwest (220° to 230°) and varying from 6 to 10 kts. The wind at North Philadelphia Airport was more westerly (240° to 250°) while Reading surface wind was calm.

B. Temperature Inversion

The temperature record shows that a strong inversion started at the fourth shear level (570-890 ft). The magnitude of the inversion was greater than 2°F/100 ft. This lasted from 0201 EST to 0331 EST. The wind shear at the same elevation was greater than 12 kts. Then, from 0501 to 0931 EST the inversion became strong at level 3 (350-570 ft) and the wind shear also moved to the same level while the temperature inversion and wind shear decreased at level 4. At the second level (100-350 ft), the temperature inversion never exceeded 1.4°F/100 ft. But for a short period, the wind shears exceeded 10 kts. This occurred from 0801 to 0901 EST.

C. Detailed Analysis of Wind Shears

A minute by minute tabulation was made of the wind speed and direction as determined from the Aervan Anemometer recording. From these wind vectors, the magnitude and direction of the wind shears for the available shear levels was calculated. These tabulations are attached.

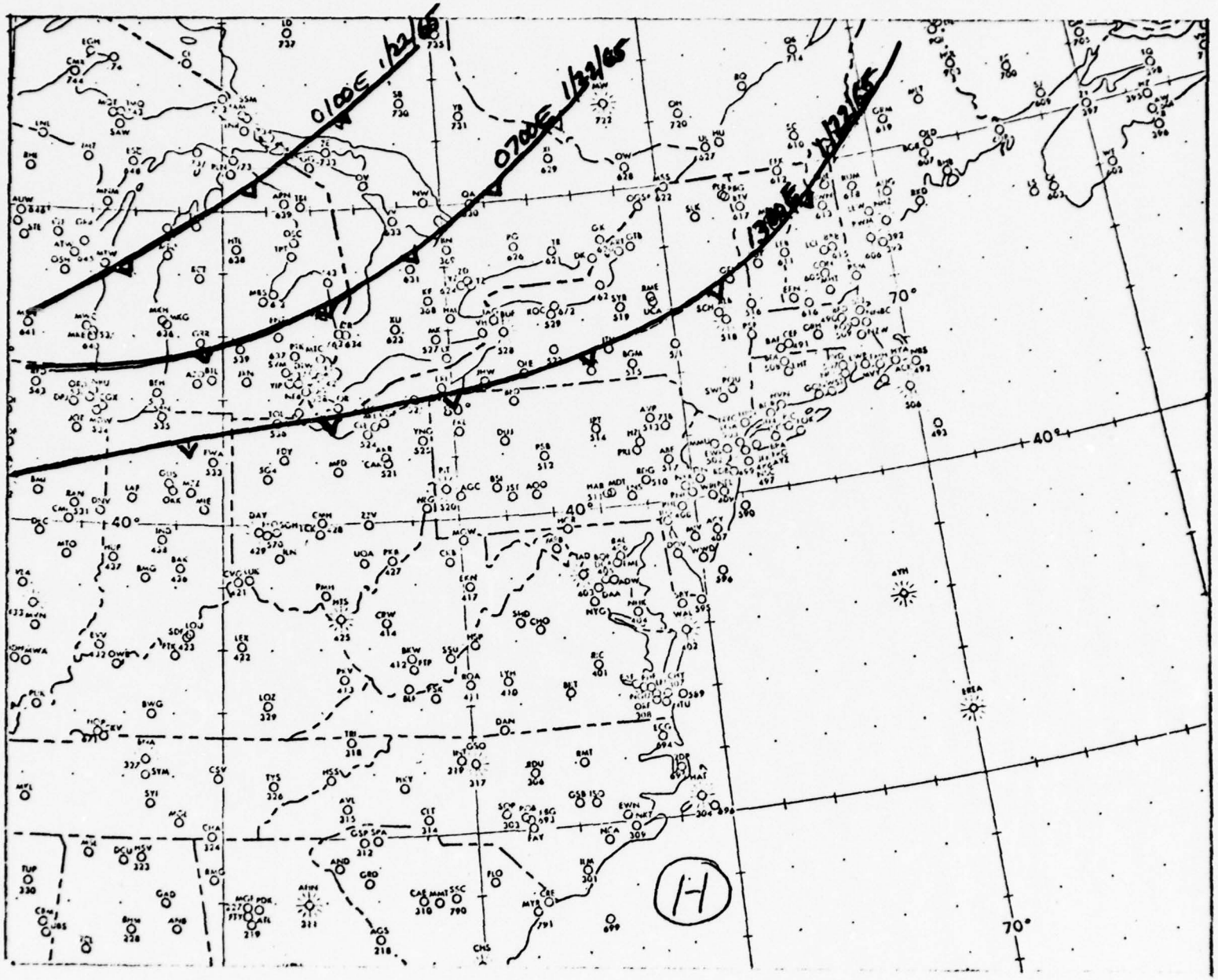
During the period 0155 to 0340 EST, the winds producing shears were at the 890 ft elevation. These were from 250° gradually veering to 270° with the wind speed 38 kt decreasing to 29 kt. At the 570 ft level, the winds were from 245° to 255° with speeds between 19 and 25 kts. This combination produced shears of 259° gradually veering to 316° with magnitudes of 16 to 10 kts. The wind at 570 ft coupled with that of 350 ft which ranged from 270° to 255° and between 15 and 21 kts caused shears of between 4 to 10 kts.

Finally, the wind at 100 ft which varied between 270° and 220° and speeds up to 6 kts produced shears of 8 to 20 kts.

During the period of 0455 to 1010 EST of January 22, 1965, the wind at the 890 ft elevation varied between 255° and 265° with speeds between 28 and 37 kts. The wind at 570 ft varied between 240° and 260° with speeds of 15 to 31 kts. This combination produced shears between 234 and 304° with magnitudes between 3 and 19 kts.

At the 350ft level the wind vector varied between 250° and 270° with speeds between 10 and 22 kts producing shears between the 570 and 350 ft elevation, level 3, of from 3 to 18 kts and with directions of between 194° and 272°.

The wind direction and speed at the 100 ft elevation varied between 180° and 275° with speeds of 6 kts or less. This resulted in shears at level 2 of 4 to 21 kts from 254° to 279°.


0100E 1/22/65
0700E 1/22/65
1300E 1/22/65
70°
40°
40°
70°
17

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of February 7, 1965

On this date, the shears exceeded the minimum criteria on a more or less continuous basis during the period 0810 to 1340 EST. There had been some occasional shears between 0010E and 0800E at levels 3 and 4. The shears that did occur at level 4 were the strongest that had been detected during the entire period of data. The shears at level 4 occurred more or less continuously, at level 3 intermittently, and not at all at level 2.

A. General Synoptic Situation

At 0700 EST, the entire central and northeastern United States was in the warm sector flow of a wave which was centered in Canada just north of Wisconsin. A cold front extended southward from the low through Iowa and then southwestward into northern Kansas. The warm front lay east-west across Canada north of the U. S. and entered the U. S. in upper New York as a stationary front thence southeastward across Cape Cod.

Another frontal wave in the southeast U. S. had a warm front oriented east-west through central South Carolina.

By 1600 EST, the fontal system had progressed as follows. The wave in Canada continued moving northeastward. The cold front extended along a line through central Lake Michigan and then southwestward into Missouri. The stationary front had become a warm front and moved northeastward. There was no warm front left in northeastern U. S.

The wave in the southeast moved northeastward to the Virginia-North Carolina border with a cold front southwestward into western South Carolina and a warm front southeastward off the coast of North Carolina. It was the overrunning from this fontal wave which caused lowering clouds and precipitation at Philadelphia by 1135 EST.

Southerly surface winds covered the area of southeastern Pennsylvania during the entire period.

During the early morning hours from midnight on layers of clouds formed and lowered at 3 to 4 thousand feet by 0755 EST and 1500 ft by 1135 EST at Philadelphia. Light rain began to fall at 1135 EST. This continued during the rest of the period. Visibility decreased from 10 to 2 1/2 miles in rain and fog. North Philadelphia Airport and Reading experienced the same weather pattern with the rain starting earlier. Surface winds were light over the area; 3 to 10 kts from 90° to 60° at the Philadelphia International Airport, from 50°to 120 ° at North Philadelphia and NAS Willow Grove, and calm at Reading. There was no frontal passage or any fronts within 600 miles of the area. The pressure began to fall rapidly at about 1335 EST and again at 1955 EST when the winds at the surface became strong and gusty, 12 to 15 kts from 160° with gusts to 30 kts.

B. Temperature Inversion

Temperature inversions occurred for a brief period at 0501. The strongest inversion was at the 3rd wind shear level, between 350 and 570 ft. At this level the inversion had a magnitude of 3.5°F/100 ft. At the same time, the fourth shear level, 570 to 890 ft, also had an inversion. This one was 2.2°F/100 ft. There were no inversions of 2°F/100 ft before or after or at any other elevation.

C. Detailed Analysis of Wind Shears

Between 0100 and 0800 EST, there were occasional occurrences of wind shears at levels 3 and 4 which met the minimum criteria for shears of significance. Beginning at 0800 and continuing until 1340 the shears became stronger and more continuous. These shears occurred at levels 3 and

4, the same elevations as the temperature inversions. A minute by minute tabulation of the wind shears from 0810 to 1340 EST is attached.

The shears were produced by the increase of wind speed with elevation particularly on the fourth level coupled with the backing of the wind direction of about 25°. This caused occasional shears at level 3 of about 8 to 9 kts from 170° to 190° between 0810 and 0955 EST. The shears at level 4 were stronger, reading 10 kts at 0822 EST and continuing until the end of the period. The strongest wind shear recorded was 18.1 kt at 1225 EST.

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of February 11, 1965

In this case wind shears occurred in conjunction with an inversion during the period 0155 to 0540 EST.

A. General Synoptic Situation

At 0100 E, an occluded front was oriented north-south from southern Maine, northward. A low pressure center, located about 250 miles east of Philadelphia had a coldfront extending southwestward into the coast of Maryland and then southwest along the Appalachian Mts. By 0700 EST, February 11, 1965 the coldfront had continued to move southeastward entering the coast along the Virginia, North Carolina border and continuing westward into Tennessee. The low pressure center continued moving eastward away from the coast.

Low clouds with poor visibility persisted in the Philadelphia area all morning. Winds at the surface were very light, generally west to northwest less than 6 kts until about 0500 EST after which the winds backed to southwest (230°) and were less than 5 kts the rest of the period. At Reading the winds were calm.

B. Temperature Inversion

The temperature inversion with a significant wind shear began at 0201 EST at level 4. The magnitude of the inversion was 4.2°F/100 ft. This inversion reached 5.4°F/100 ft at 0231 EST and then gradually decreased in strength to 0.7°F/100 ft at 0531. The lapse rate at level 3 started at -0.1°F/100 ft at 0201 EST reaching a maximum inversion of 6.7°F/100 ft at 0531. The lapse rate at level 2 never exceeded isothermal conditons during the period.

C. Detailed Analysis of Wind Shears

A detailed tabulation of wind shears for each minute from 0155 to 0540 was prepared from the analog records of the Aerovane Anamometer and is attached. These tabulations show that the shears reached 18 to 19 kts at the level 4 at the beginning of the period. The shears then decreased at level 4 to elss than 10 kts by 0320. There were brief periods of shears larger than 10 kts thereafter but generally the shears decreased to zero by the end of the period.

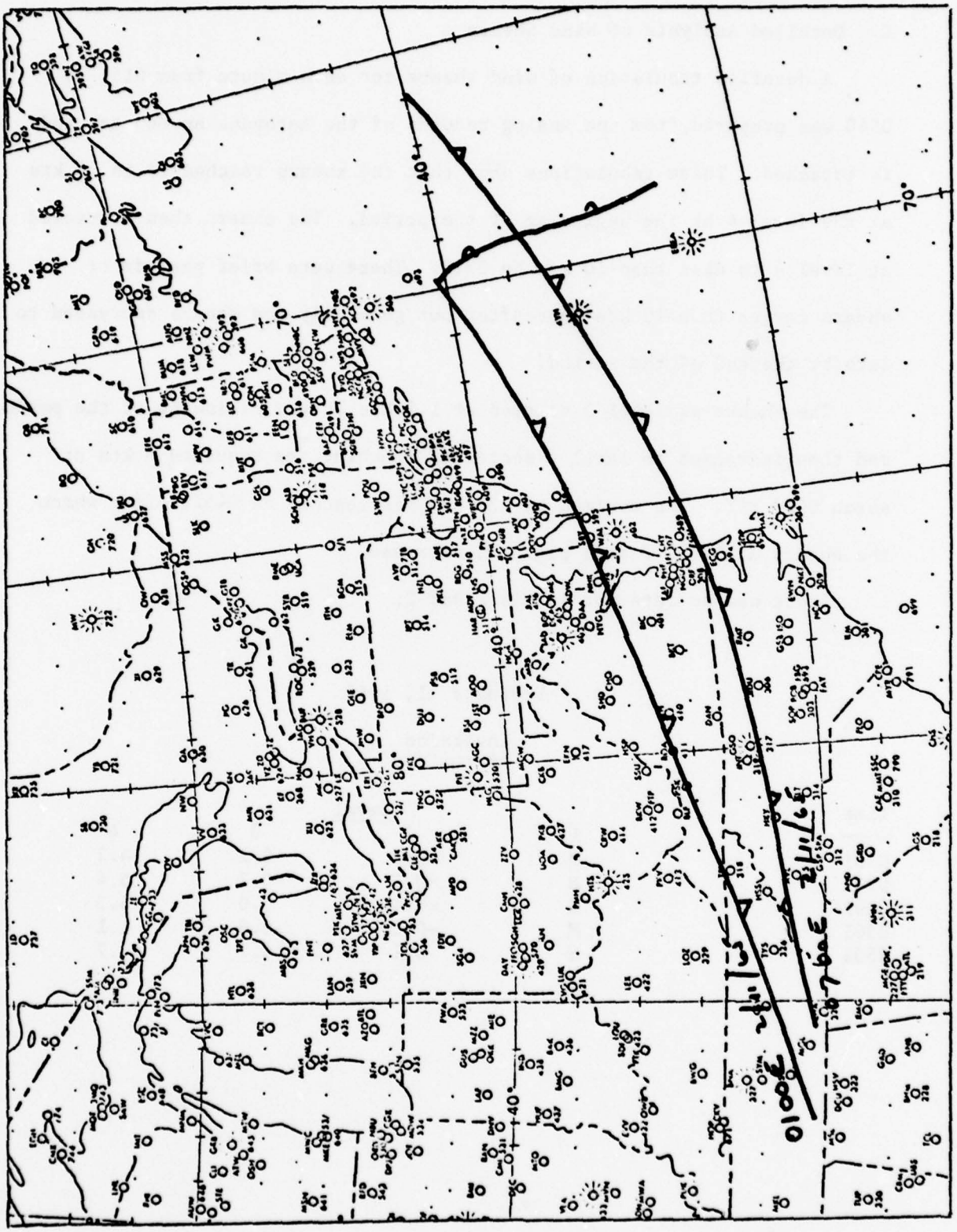
The shears at level 3 started at 1.2 kts at the beginning of the period and then increased as level 4 decreased reaching the required 8 kts at abtou 0423 EST. The maximum of 153 kts was reached at 0452, after which the shears at level 3 also began to decrease.

There was no data for levels 1 and 2.

February 11, 1965

Inversion
F°/100 ft

Time	Level			
	1	2	3	4
0201	M	-0.2	-0.1	4.2
0231	M	-0.2	-0.2	5.4
0301	M	-0.4	0.0	4.3
0501	M	-0.3	6.6	1.1
0531	M	0.1	6.7	0.7



Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of October 3, 1965

Between 0310 and 0740 EST there were continuous shears meeting the minimum criteria for level 2 and intermittent shears at level 3. No shears met the 10 kt criterion at level 4. In this case, there was an inversion at level 2 of greater than 2°F/100 ft and none above that level.

A. General Synoptic Situation

At 0100 E, October 3, 1965 a low pressure center was located just south of Hudson Bay in Canada. A cold front extended out of the low just east of Lake Huron, through Detroit, central Indiana, southern Illinois and into northern Michigan. A cold front had passed eastward off the coast the day before. At 0100 E, October 3, 1965 the southern end of that front entered the east coast of the U. S. as a northeast-southwest oriented stationary front at Jacksonville, Florida.

By 1000 EST, October 3, 1965 the cold front that had been at Detroit had moved to central Pennsylvania and the stationary front in Florida had moved slightly ~~southeastward~~.

The surface wind flow over southeastern Pnnnsylvania was westerly at 0100 E and became south westerly as the morning progressed. Wind speeds were 4-5 kts gradually increasing to 10 kts by 0800 EST, with gusts developing by late morning. The sky was clear and visibility was unrestricted.

B. Temperature Inversion

Temperature inversions of greater than 2°F/100 ft were first reported at 03.0 EST at level 2. The value was 3.6°F/100 ft (100-350 ft). The lapse rate was isothermal at level 3 (350-570 ft) and -0.4°F/100 ft at level 4 (570-890 ft). The strong inversion persisted until 0510 EST at level 2 while the upper levels remained essentially isothernal.

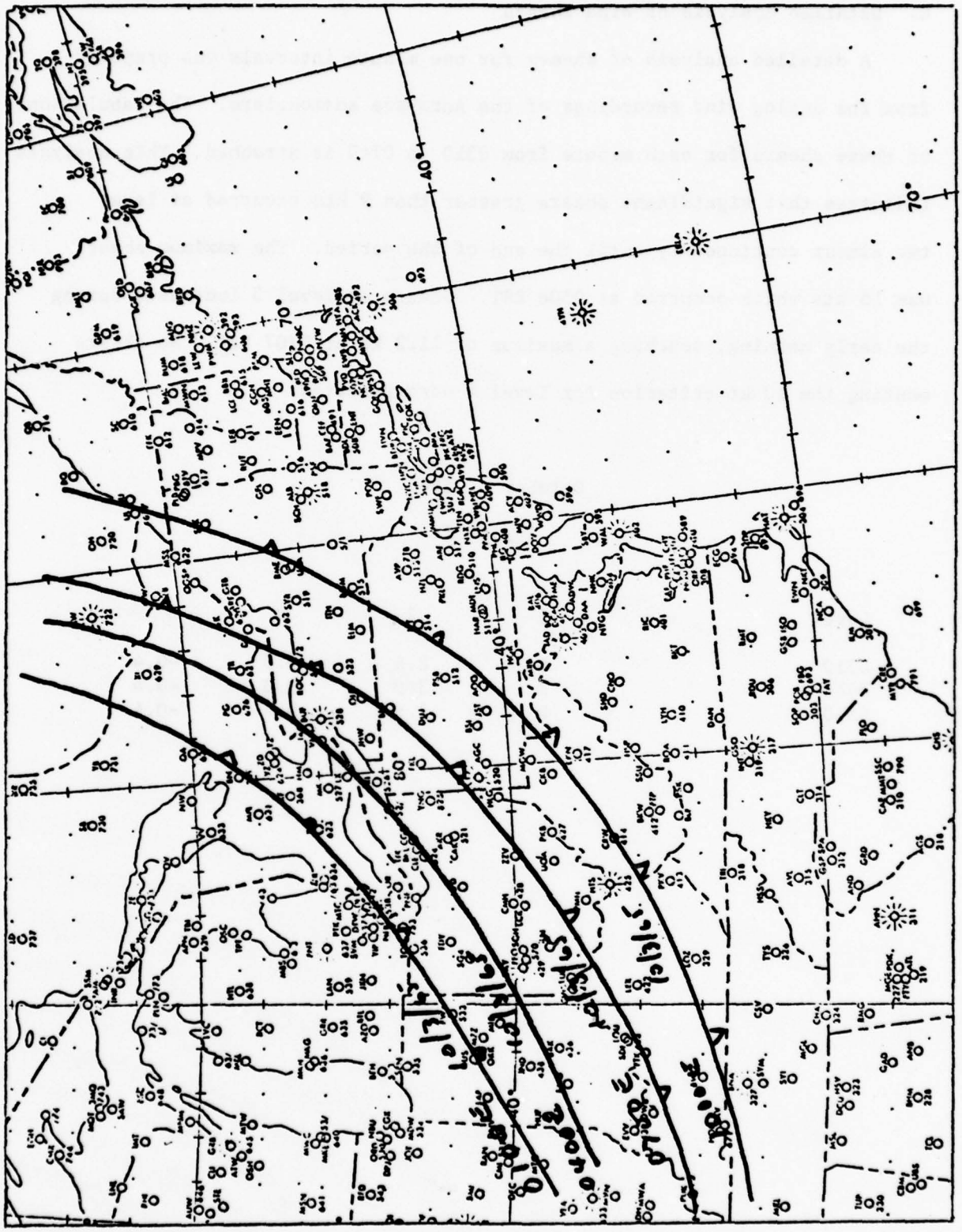
C. Detailed Analysis of Wind Shears

A detailed analysis of shears for one minute intervals was prepared from the analog wind recordings of the Aerovane anemometers. The tabulations of these shears for each minute from 0310 to 0740 is attached. This analysis indicates that significant shears greater than 9 kts occurred at level two almost continuously until the end of the period. The maximum shear was 15 kts which occurred at 0508 EST. Shears at level 3 increased during the early morning, reaching a maximum of 11.2 kt at 0707 EST. No shears meeting the 10 kt criterion for level 4 were reported.

October 3, 1965

F°/100 ft

Level	1	2	3	4
0310	M	2.6	0.3	-0.4
0440	M	3.0	0.0	-0.4
0510	M	2.6	0.4	-0.4



Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of December 31, 1965

In this case, shears had been occurring intermittently from December 29, 1965 until January 1, 1966. A portion of that period, 0040 to 0825 EST of December 31, 1965 was examined in detail. Shears occurred at various times at levels 2, 3, and 4. In addition, inversions of greater than $2^{\circ}F/100$ ft. were present at levels 3 and 4. Also inversions less than $2^{\circ}F/100$ ft. were present at level 2.

A. General Synoptic Situation

A low pressure center was located at 2200E, December 30, 1965 in southern Minnesota. A stationary front extended eastward out of the low through central Lake Michigan and then North eastward through upper Lake Huron. A cold front was along a line from the low center southward through eastern Nebraska. The low center moved slowly north eastward to central Lake Superior by 1000 E, December 31, 1965 with the cold front along a line lengthwise through Lake Michigan and across central Missouri. The stationary front moved northward into Canada as a Warm-front. The area east of the low was in prevailing south westerly flow.

Layers of middle clouds covered southeastern Pennsylvania most of the morning of December 31, 1965 except for a brief period of clear sky from 0455 to 0630 EST of December 31, 1965. Visibility was restricted to 5-6 miles due to smoke and haze and gradually decreased to 1 mile by 0836 EST with the addition of ground fog. Surface winds were southwest 4 to 7 kts. These conditions generally prevailed in the Philadelphia area. At Reading, the sky was broken at 6000 ft. lowering to overcast at 4000 ft. by 0755 EST and visibility of 6 to 7 miles decreased to 4 to 5 miles. The surface winds at Reading were calm all morning.

B. Temperature Inversion

There were temperature inversions of greater than $2^{\circ}F/100$ ft. almost continuously at levels 3 and 4. The inversion started at $2.2^{\circ}F/100$ ft. at level 3 and $2.8^{\circ}F/100$ ft. at level 4. The laserate below level 3 was less than isothermal. As the morning progressed, the inversion at level 4 increased to $3.4^{\circ}F/100$ ft. by 0155 EST then gradually decreased to $1.1^{\circ}F/100$ ft. by 0355 EST and increased to $3.3^{\circ}F/100$ ft. by 0525 EST with slight decreases and increases by 0755 EST after which the inversion decreased.

At level 3, the inversion of $2.2^{\circ}F/100$ ft. at 0040 EST increased in strength to a maximum of $5.6^{\circ}F/100$ ft. at 0355. This then decreased to $2.6^{\circ}F/100$ ft. by 0525 EST and then increased to $6.4^{\circ}F/100$ ft. at 0640 EST decreasing and increasing thenafter to isothermal conditions by 1240 EST. The lapse rate at level 2 was essentially isothermal all morning.

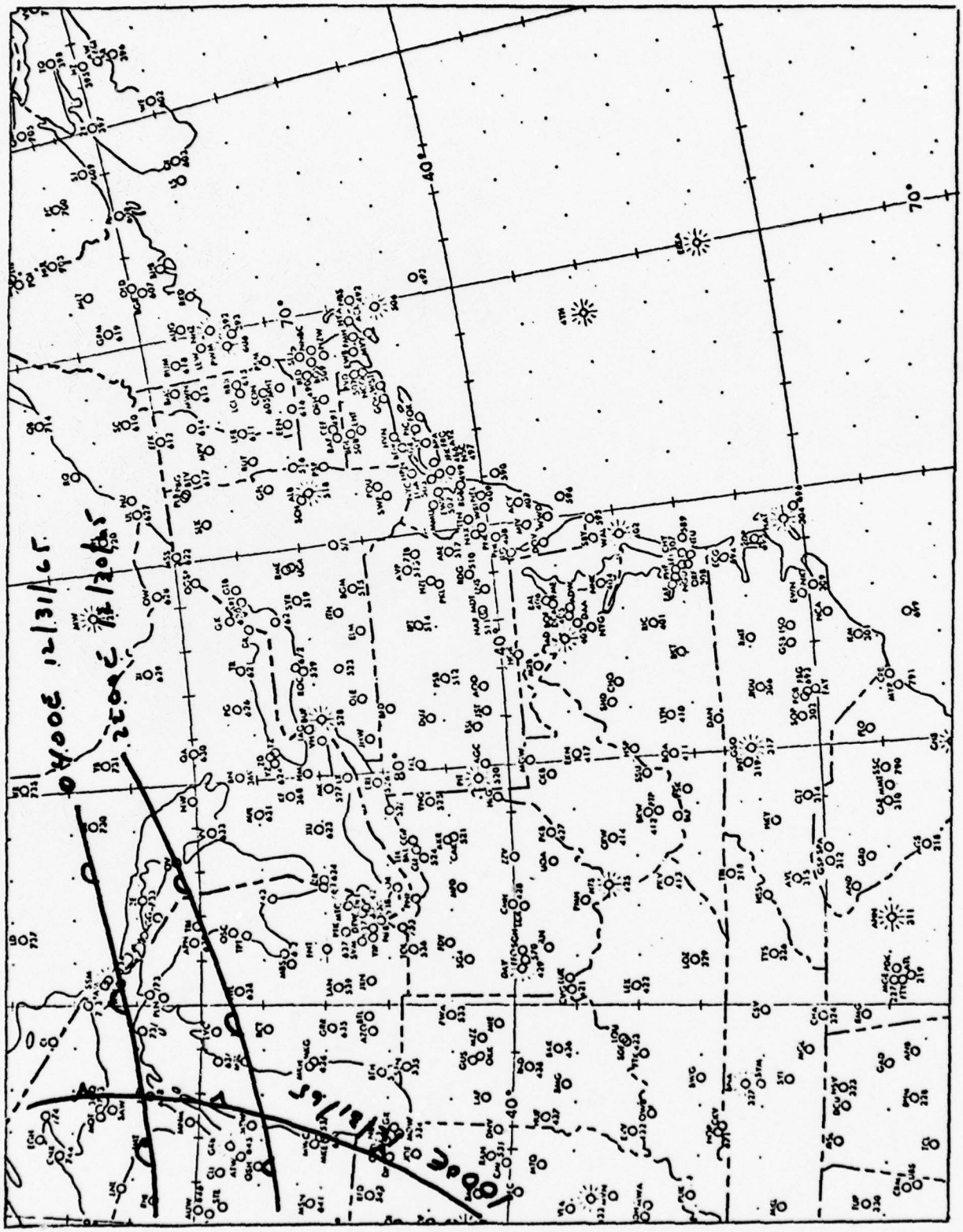
C. Deatailed Analysis of Wind Shears

This is a particularly long period of wind shear lasting from 0040 to 1040 EST, December 31, 1965. A minute by minute tabulation of wind shears at each level was determined from the analog records of the Aerwand anemometer. This tabulation is attached. Shears meeting the minimum criterion of 9 kts. for level 2 were observed intermittently at the beginning of the period. These became stronger and more continuous by 0400 and then decreased to below 9 kts. by 0825 EST.

At level 3 the shears exceeded 8 kts. essentially the entire period reaching a maximum of 19.1 kts. at 0955 and 1003 EST. The Shears at level 4 were quite small and did not reach the 10 kt. mimimum until 0600 EST. The direction of the shears were generally 230°-250° at level 2 230°-250° at level 3 and generally 120°-150° at level 4.

December 31, 1965

		Inversion	F^{o}/100ft.		
	Level	1	2	3	4
Time	0040	M	-0.2	2.2	2.8
	0055	M	-0.2	3.3	2.5
	0155	M	-0.1	2.5	3.4
	0210	M	-0.2	3.0	2.9
	0225	M	0.1	3.5	2.5
	0240	M	0.0	3.8	2.4
	0255	M	0.1	3.7	2.6
	0310	M	0.4	3.9	2.4
	0325	M	0.4	4.6	1.8
	0340	M	0.4	4.8	1.9
	0355	M	0.8	5.6	1.1
	0410	M	0.4	5.1	1.7
	0425	M	0.4	3.6	2.7
	0440	M	0.5	3.9	2.5
	0455	M	0.5	3.4	2.9
	0510	M	0.3	3.4	2.8
	0525	M	0.2	2.6	3.3
	0540	M	0.2	4.8	2.1
	0555	M	0.3	4.1	2.5
	0640	M	0.8	6.4	0.7
	0755	M	0.1	3.1	3.2
	0940	M	-0.3	4.0	1.6
	0955	M	-0.1	5.1	0.7
	1010	M	-0.3	4.5	0.8
	1025	M	-0.2	3.6	1.0
	1040	M	-0.2	2.5	1.0
	1155	M	-0.4	0.4	2.1
	1240	M	-0.6	0.2	2.2



Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of March 11, 1966

On this date, strong inversions occurred at the same time as wind shears which met the minimum criteria. The shears resulted from the increase in wind speed with elevation mainly between the 570 and 890 ft. levels. The shears and inversions occurred between the hours of 0040 and 0510 EST.

A. General Synoptic Situation

At 2200 EST of March 10, 1966 a coldfront lay along a line east-west through central Michigan, central New York, Vermont and New Hampshire. A high pressure area was centered over north eastern North Carolina with a ridge of higher pressure northward through central Pennsylvania with a col at the front.

During the next six hours the front moved slowly southward to the New York, Pennsylvania border while the high pressure center in North Carolina remained stationary. The ridge moved eastward to east of New Jersey and the flow became more regularly south westerly around the high over eastern Pennsylvania.

By 0700 E, March 11, 1966, the cold front had progressed southward to north central Pennsylvania and over Long Island. The anti cyclone began to move slowly eastward over the Atlantic.

Broken to overcast altcumulus clouds at about 8000 to 9000 ft. prevailed over the area of southeastern Pennsylvania during the period of the shears and inversion (0040 to 0510 EST). Visibility was generally better than 6 miles. Light rain began in the area at 1030 EST in the Philadelphia area and about one hour earlier at Reading. Surface winds were from 220 to 230°, six to nine knots.

B. Temperature Inversion

During the period, the strongest inversions, greater than $2^{\circ}F/100$ ft. occurred at level 4. These strong inversions lasted from 0040 to 0225 EST. The lapse rate was nearly isothermal below the fourth level.

Temperature $F^{\circ}/100$ ft.

	Level	1	2	3	4
Time	0040	M	-0.4	-0.1	2.5
	0110	M	-0.3	0.5	2.7
	0125	M	0.0	0.4	2.8
	0140	M	-0.1	0.3	2.8
	0155	M	-0.2	0.4	2.9
	0210	M	-0.2	0.2	2.9
	0225	M	-0.3	0.2	3.4

C. Detailed Analysis of Wind Shears

While this inversion between 570 and 890 ft. persisted, the wind shear at the same level exceeded the minimum criteria with values of 12 to 14 kts.

The wind shear at the third level (350 to 570 ft.) occasionally exceeded 8 kts.

A detailed analysis of the wind shear by minutes from 0040 to 0510 EST was determined from the analog records of the Aerovane Anemometers. The tabulation of these shears are attached. This analysis showed essentially no shears below the third level except for a few minutes between 0244 and 0259. The rest of the time, the shears at level 2 were of the order of 2 to 5 kts.

At the third level, shears exceeded 8 kts. form 0041, intermittently less, to 0323 after which the shears gradually decreased in strength to 3 to 5 kts. except for the last four minutes of the period. On the other

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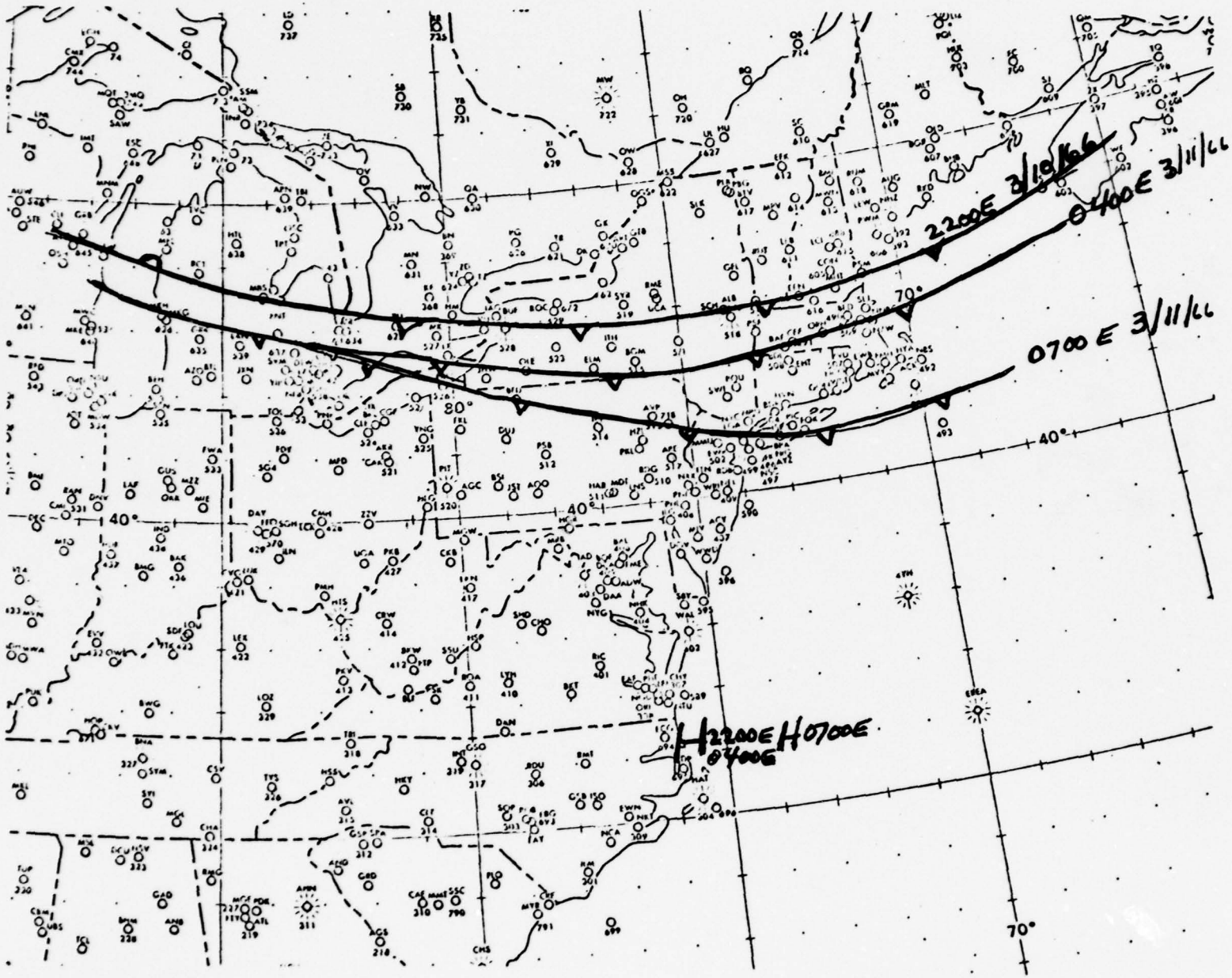
hand, shears exceeded the required 10 kts. the entire period except for 0235 to 0301.

The shear direction veered with height from 220° to 240° at level 2, 240° to 260° at level 3, to 245° to 285° at level 4.


2200E 3/10/66
0400E 3/11/66
0700E 3/11/66
H2200E H0700E
07006
70°
80°
40°
40°
40°
70°

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of December 17, 1966

On this date, shears occurred between 0310 and 0840 EST. There were no fronts in the area. There was an inversion at level 1 which was associated with the shears.

A. General Synoptic Situation

At 0100 E, December 17, 1966 a large high pressure ridge lay off the east coast of the U.S. The high was centered over eastern North Carolina. A low pressure area was centered over Lake Superior with a stationary front extending north eastward into Canada and a cold front westward along the U.S.-Canada border. Another cold front extended south westward from the low to the South Dakota, Nebraska border. South westerly wind dominated the entire north eastern U.S. By 0700 E, there was essentially no change except the low had moved to just north of Lake Huron and the high had moved eastward off the east coast. The second cold front has followed along with the low.

During the morning of December 17, 1966, in the vicinity of Philadelphia, the sky was clear to scattered high clouds. Visibility was restricted to 2 to 4 miles in ground fog and smoke. Surface winds were south westerly 3 to 5 kts.

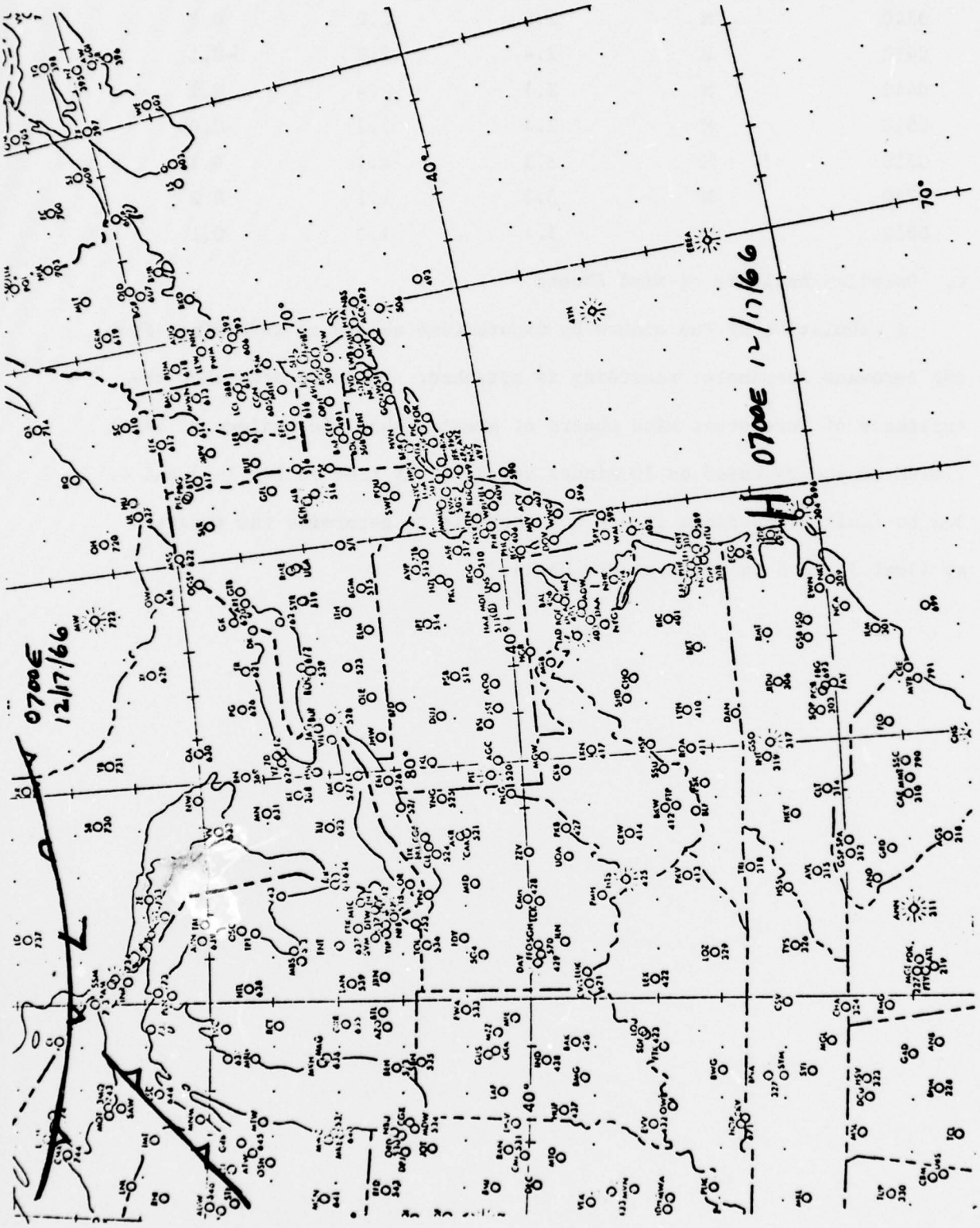
B. Temperature Inversion

Temperature inversion greater than $2^{o}F/100$ ft. occurred from 0340 throughout the period at levels 2 and 3. The strongest inversions were at level 2. The strongest wind shears were also at level 2.

		Temperature F^{o}/100 ft.			
	Level	1	2	3	4
Time	0340	M	2.8	2.0	0.1
	0410	M	2.4	2.9	-0.1
	0440	M	2.1	2.4	0.1
	0510	M	2.4	2.2	0.0
	0710	M	3.3	2.1	0.1
	0740	M	3.3	1.1	0.2
	0810	M	3.1	1.1	0.1

C. Detailed Analysis of Wind Shears

A tabulation of the minute by minute wind shears as determined from the Aerovane Anemometer recording is attached. These records show the existence of persistent wind shears of greater than the minimum at level 1 with no shears based on 10 minute averages any time at levels 3 and 4. Due to faulty recordings it was not possible to determine the shears at level 3 and 5 on a one minute basis.


07002 12/17/66
07002 12/17/66
H
L
80°
70°
40°

Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

Case of September 15, 1967

On this date shears were stronger from 0010 to 0710. There had been shears beginning at 2210 EST, September 14, 1967 and some continued after the period till 1040 EST of September 16, 1967. There were shear records for levels 1 and 2. The interesting feature on this date was the existence of two hurricanes in the Atlantic: Chloe - esat of Bermuda and Doria which was about 250 miles south east of Cape Cod.

A. General Synoptic Situation

At 2200 E September 14, 1967 a high pressure ridge extended southward from Canada into western Pennsylvania, Maryland and Virginia. Hurricane Doria was located at 38.8°N 67.0°W, about 250 miles SE of Cape Cod. During the next 9 hours, the ridge of pressure remained stationary while Doria moved westward 50 miles. The wind field over South eastern Pennsylvania was NE, controlled by the Anticyclonic flow of the high and the Cyclonic flow of Doria.

There were high thin clouds over south eastern Pennsylvania with visibility better than 10 miles except for some ground fog at Reading by 0600 EST. Surface winds were NNE 7 to 8 kts. except calm at Reading.

B. Temperature Inversions

Temperature inversions occurred at levels 1 and 2 which exceeded 2°F/100 ft.

		Temperature F°/100 ft.			
	Level	1	2	3	4
Time	0125	3.0	2.2	0.7	-0.3
	0155	2.5	2.1	0.5	-0.1
	0210	2.3	2.0	0.5	-0.2

C. Detailed Analysis of Wind Shears

Records to determine wind shears at levels 3 and 4 were not available. but the 10 minute wind data showed strong wind shears of 12 to 13 kts. at level 2. Level 1 was less than 5 kts. The minute by minute tabulation of the wind shears is attached. They show Northeasterly shears greater than 9 kts. at level 2 during the entire period.

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DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 10	2	350	6	340	14	35				
		4.1	335	11.7	60					
11	2	350	6	335	14	35				
		4.1	328	12.2	61					
12	2	350	6	340	14	35				
		4.1	335	11.7	60					
13	2	350	6	340	14	30				
		4.1	335	11.1	54					
14	2	350	6	340	14	30				
		4.1	335	11.1	54					
15	3	355	6	335	14	30				
		3.3	317	11.7	53					
16	3	350	6	340	14	35				
		3.1	330	11.7	60					
17	2	350	7	335	14	35				
		5.1	329	12.1	65					
18	2	350	7	335	14	35				
		5.1	329	12.1	65					
19	3	345	7	335	14	30				
		4.1	328	11.5	60					
20	3	350	7	335	14	30				
		4.2	324	11.5	60					
21	3	345	7	335	13	30				
		4.1	328	10.7	63					
22	3	350	7	335	13	30				
		4.2	324	10.7	63					
23	3	345	8	330	13	30				
		5.2	321	11.4	68					
24	2	340	7	335	12	30				
		5.0	329	9.8	66					

DETAILED WIND SHEAR ANALYSIS

Year 1967 Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 25	2	235	7	330	12	30				
		5.0	328	10.4	66					
26	3	350	7	330	12	25				
		4.3	316	9.8	61					
27	3	350	7	330	12	25				
		4.3	316	9.8	61					
28	2	345	7	335	12	25				
		5.0	331	9.2	61					
29	3	345	7	330	12	20				
		4.2	319	9.2	56					
30	2	340	7	330	12	20				
		5.0	326	9.2	56					
31	3	350	7	330	12	20				
		4.3	316	9.2	56					
32	3	345	7	330	13	20				
		4.2	319	10.1	52					
33	2	340	7	330	13	20				
		5.0	326	10.1	52					
34	3	350	7	330	13	20				
		4.3	316	10.1	52					
35	3	350	6	335	13	25				
		3.2	321	10.2	52					
36	2	345	7	335	13	20				
		5.0	331	9.5	52					
37	2	345	7	330	14	25				
		5.1	324	11.5	55					
38	3	350	6	330	14	20				
		3.3	312	11.1	44					
39	3	345	6	330	14	20				
		3.2	316	11.1	44					

DETAILED WIND SHEAR ANALYSIS

Year 1967 Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 40	3	350	7	330	14	20				
		4.3	316	10.9	49					
41	4	345	7	330	14	20				
		3.3	312	10.9	49					
42	3	345	7	330	14	25				
		4.2	319	11.5	55					
43	3	340	7	330	14	25				
		4.1	323	11.5	55					
44	4	345	7	330	14	25				
		3.3	312	11.5	55					
45	4	345	8	330	15	20				
		4.3	316	11.6	52					
46	3	345	7	335	15	25				
		4.1	328	11.8	52					
47	4	5	6	330	15	25				
		3.6	290	12.6	48					
48	4	345	7	335	15	25				
		3.1	322	11.8	52					
49	3	340	8	335	15	25				
		5.0	332	11.6	57					
50	2	20	7	330	14	30				
		5.9	315	12.1	60					
51	2	40	5	330	12	25				
		4.7	306	10.0	49					
52	3	15	5	345	13	20				
		2.8	313	9.4	38					
53	3	345	6	350	12	25				
		3.0	355	7.9	51					
54	2	15	6	330	13	25				
		4.8	313	10.8	52					

DETAILED WIND SHEAR ANALYSIS

Year 1967 Month 9 Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 55	3	15	5	330	13	25				
		3.6	294	10.9	47					
56	3	345	5	335	12	25				
		2.1	321	9.6	49					
57	3	345	6	350	12	30				
		3.0	355	8.4	58					
58	3	345	6	335	12	25				
		3.1	325	9.4	54					
59	2	350	7	330	13	25				
		5.2	322	10.7	58					
100	2	5	6	335	12	25				
		4.4	322	9.4	54					
01	3	350	5	335	13	25				
		2.2	315	10.5	46					
02	3	340	7	340	14	25				
		4.0	340	10.3	54					
03	2	345	8	340	13	30				
		6.0	338	10.0	68					
04	3	0	6	330	13	20				
		3.7	306	10.2	47					
05	4	345	6	335	14	20				
		2.2	316	10.6	44					
06	3	340	8	340	14	20				
		5.0	340	9.4	53					
07	3	345	8	330	14	20				
		5.2	321	10.8	55					
08	3	345	7	330	14	20				
		4.2	319	10.9	49					
109	3	335	8	330	14	20				
		5.0	327	10.8	55					

DETAILED WIND SHEAR ANALYSIS

Year 1967 Month 9 Day 5

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 110	3	345	8	330	15	20				
		5.2	321	11.6	52					
11	3	340	7	330	15	20				
		4.1	323	11.8	47					
12	4	345	8	330	16	20				
		4.3	316	12.5	49					
13	3	345	7	330	16	20				
		4.2	319	12.7	45					
14	3	345	7	330	16	20				
		4.2	319	12.7	45					
15	3	0	8	330	15	25				
		5.6	314	12.3	57					
16	2	350	7	335	15	25				
		5.1	329	11.8	52					
17	3	345	8	335	15	25				
		5.1	329	11.6	57					
18	3	345	7	335	16	25				
		4.1	328	12.7	50					
19	3	345	7	335	16	25				
		4.1	328	12.7	50					
20	3	345	7	340	16	25				
		5.0	338	12.1	49					
21	2	345	7	340	15	25				
		5.0	338	11.2	51					
22	3	345	7	340	16	25				
		4.0	335	12.1	49					
23	3	350	7	335	16	25				
		4.2	324	12.7	50					
24	2	350	7	335	16	25				
		5.1	329	12.7	50					

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DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 1125	3	355	6	340	16	30				
		3.2	326	13.0	51					
26	3	350	7	340	16	30				
		4.1	333	12.7	55					
27	2	350	7	340	16	25				
		5.0	336	12.1	49					
28	3	355	7	340	16	30				
		4.2	329	12.7	55					
29	2	350	7	340	16	25				
		5.0	336	12.1	49					
130	2	345	7	340	16	25				
		5.0	335	12.1	49					
31	3	345	7	340	16	25				
		4.0	336	12.1	49					
32	3	345	7	340	16	25				
		4.0	336	12.1	49					
33	2	350	7	340	16	25				
		5.0	336	12.1	49					
34	3	355	7	340	16	25				
		4.2	329	12.1	49					
35	4	355	7	345	16	25				
		3.1	332	11.6	48					
36	3	355	6	340	16	25				
		3.2	326	12.5	45					
37	4	0	6	350	16	25				
		2.2	331	11.6	42					
38	4	355	6	350	16	25				
		2.1	340	11.6	42					
139	4	355	7	350	16	25				
		3.0	343	11.0	46					

DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 140	3	355	7	345	16	25				
		4.1	338	11.6	48					
41	3	355	7	345	16	25				
		4.1	338	11.6	48					
42	3	350	7	350	16	25				
		4.0	350	11.0	46					
43	3	355	7	350	16	25				
		4.0	346	11.0	46					
44	4	0	7	350	17	25				
		3.1	337	12.0	45					
45	4	350	7	350	17	25				
		3.0	350	12.0	45					
46	4	355	7	345	17	25				
		3.1	332	12.5	46					
47	4	355	7	345	18	25				
		3.1	332	13.4	45					
48	4	355	7	350	18	25				
		3.0	343	12.9	43					
49	3	355	7	345	18	25				
		4.1	338	13.4	45					
50	3	350	7	345	18	25				
		4.0	341	13.4	45					
51	4	350	6	345	18	25				
		2.1	335	14.0	41					
52	3	355	7	345	18	25				
		4.1	338	13.4	45					
53	3	355	7	345	18	25				
		4.1	338	13.4	45					
154	3	0	7	345	18	25				
		4.2	334	13.4	45					

DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 155	3	355	6	345	18	25				
		3.1	335	14.0	41					
56	3	355	7	345	18	25				
		4.1	338	13.4	45					
57	3	355	7	345	17	25				
		4.1	338	12.5	46					
58	3	350	8	345	18	25				
		5.0	342	12.9	48					
59	4	350	8	345	18	25				
		4.0	340	12.9	48					
200	4	0	7	350	18	25				
		3.1	337	12.9	43					
01	4	355	7	345	18	25				
		3.1	332	13.4	45					
02	3	350	7	350	19	25				
		4.0	350	13.9	42					
03	2	355	6	345	19	25				
		4.1	340	14.9	40					
04	4	355	6	350	18	25				
		2.1	340	13.5	40					
05	4	355	7	350	18	25				
		3.0	343	12.9	43					
06	4	355	7	350	18	25				
		3.0	343	12.9	43					
07	4	355	8	350	18	25				
		4.0	345	12.3	47					
08	4	355	8	345	18	25				
		4.1	335	12.9	48					
209	3	355	7	345	18	25				
		4.1	338	13.4	45					

DETAILED WIND SHEAR ANALYSIS

Year 1967 Month 9 Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 210	3	355	7	345	18	25				
		4.1	338	13.4	45					
11	3	350	7	345	18	30				
		4.0	341	14.0	51					
12	3	0	7	345	19	30				
		4.2	334	14.9	49					
13	3	355	7	345	18	30				
		4.1	338	14.0	51					
14	3	355	7	345	19	30				
		4.1	338	14.9	49					
15	3	355	7	345	18	30				
		4.1	338	14.0	51					
16	3	0	7	345	18	30				
		4.2	334	14.0	51					
17	3	0	7	350	18	30				
		4.1	343	13.4	50					
18	3	0	7	345	18	30				
		4.2	334	14.0	51					
19	3	355	6	345	18	30				
		5.0	348	13.4	50					
20	3	0	6	350	18	25				
		3.1	340	13.5	40					
21	3	355	6	350	18	25				
		3.0	345	13.5	40					
22	3	355	6	350	18	25				
		3.0	345	13.5	40					
23	3	355	6	350	18	25				
		3.0	345	13.5	40					
224	3	0	6	350	18	25				
		3.1	340	13.5	40					

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DETAILED WIND SHEAR ANALYSIS

Year 19 71 Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 225	3	355	6	350	17	25				
		3.0	345	12.6	41					
26	3	355	6	350	18	25				
		3.0	345	13.5	40					
27	4	0	6	345	18	25				
		2.4	319	14.0	41					
28	4	350	6	350	18	25				
		2.0	350	13.5	40					
29	3	355	7	350	18	25				
		4.0	346	12.9	43					
230	3	355	7	345	18	25				
		4.1	338	13.4	45					
31	3	350	7	345	18	25				
		4.0	341	13.4	45					
32	3	0	7	340	18	25				
		4.3	326	14.0	46					
33	3	355	7	345	18	25				
		4.1	338	13.4	45					
34	3	350	6	345	18	25				
		3.0	340	14.0	41					
35	3	350	7	345	18	25				
		4.0	341	13.4	45					
36	3	355	7	345	18	25				
		4.1	338	13.4	45					
37	3	355	7	345	18	25				
		4.1	338	13.4	45					
38	3	350	7	345	18	25				
		4.0	341	13.4	45					
239	3	350	7	345	18	25				
		4.0	341	13.4	45					

DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 240	3	355	8	345	18	25				
		5.1	334	13.0	48					
41	3	350	8	345	18	25				
		5.0	342	13.0	48					
42	3	355	7	340	18	25				
		4.2	329	14.0	46					
43	3	355	7	340	18	25				
		4.2	329	14.0	46					
44	3	355	7	345	18	25				
		4.1	338	13.4	45					
45	3	355	8	345	18	25				
		5.1	339	13.0	48					
46	3	355	7	340	18	25				
		4.2	329	14.0	46					
47	3	0	8	340	18	25				
		5.3	329	13.6	50					
48	4	355	8	345	18	25				
		4.1	335	13.0	48					
49	3	355	7	345	17	25				
		4.1	338	12.5	46					
50	3	0	7	345	17	25				
		4.2	334	12.5	46					
51	3	350	7	345	18	25				
		4.0	341	13.4	45					
52	3	355	7	350	18	25				
		4.0	346	12.9	43					
53	4	355	7	345	18	25				
		3.1	332	13.4	45					
254	3	0	7	345	18	25				
		4.2	334	13.4	45					

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DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 255	3	0	7	345	18	25				
		4.2	334	13.4	45					
56	3	0	7	345	18	25				
		4.2	334	13.4	45					
57	3	0	7	345	18	25				
		4.2	334	13.4	45					
58	4	0	7	345	18	25				
		3.3	327	13.4	45					
59	3	10	7	350	18	25				
		4.3	336	12.9	43					
300	4	5	7	355	18	25				
		3.1	342	12.4	41					
01	4	10	7	350	18	30				
		3.5	327	13.4	50					
02	3	10	7	355	18	30				
		4.2	344	12.9	48					
03	3	5	7	355	18	30				
		4.1	348	12.9	48					
04	3	355	7	355	18	30				
		4.0	355	12.9	48					
05	3	355	6	355	18	30				
		3.0	355	13.5	45					
06	3	355	7	355	18	30				
		4.0	355	12.9	48					
07	3	355	6	355	18	30				
		3.0	355	13.5	45					
08	3	355	6	355	18	30				
		3.0	355	13.5	45					
309	4	0	7	355	18	25				
		3.0	348	12.4	41					

DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 310	4	355	6	350	18	25				
		2.1	340	13.5	40					
11	3	355	7	350	18	30				
		4.0	346	13.4	50					
12	3	355	7	350	18	25				
		4.0	346	12.9	43					
13	3	355	6	350	18	25				
		3.0	345	13.5	40					
14	3	355	6	350	18	30				
		3.0	345	13.5	40					
15	3	0	7	355	18	30				
		4.0	351	12.9	48					
16	3	0	7	350	18	30				
		4.1	343	13.4	50					
17	3	0	7	355	18	25				
		4.0	351	12.4	41					
18	3	0	7	355	18	25				
		4.0	351	12.4	41					
19	3	355	6	355	18	30				
		3.0	355	13.5	45					
20	3	355	6	355	18	30				
		3.0	355	13.5	45					
21	3	0	7	350	18	30				
		4.1	343	13.4	50					
22	3	0	7	350	18	30				
		4.1	343	13.4	50					
23	3	0	6	355	18	30				
		3.0	350	13.5	45					
324	4	0	6	355	18	30				
		2.1	345	13.5	45					

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DETAILED WIND SHEAR ANALYSIS

Year 1967 Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 325	3	0	6	350	18	30				
		3.1	340	14.0	46					
26	4	0	7	350	18	30				
		3.1	337	13.4	50					
27	3	0	8	355	18	30				
		5.0	352	12.3	52					
28	4	0	7	355	18	30				
		3.6	348	12.9	48					
29	2	0	6	350	18	30				
		4.1	345	14.0	46					
330	3	10	6	350	18	30				
		3.3	332	14.0	46					
31	3	0	7	355	18	30				
		4.6	351	12.9	48					
32	3	0	6	355	18	30				
		3.0	350	13.5	45					
33	3	10	6	355	18	30				
		3.2	341	13.5	45					
34	4	0	6	355	18	30				
		2.1	345	13.5	45					
35	3	0	7	350	18	30				
		4.1	343	13.4	50					
36	3	0	7	0	18	30				
		4.0	0	12.4	46					
37	4	0	6	355	18	30				
		2.1	345	13.5	45					
38	3	0	7	355	19	30				
		4.0	351	13.9	47					
339	3	5	7	355	19	30				
		4.1	348	13.9	47					

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DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 340	3	10	7	355	19	30				
		4.2	344	13.9	47					
41	4	355	7	350	19	30				
		3.0	343	14.4	48					
42	4	0	7	355	19	30				
		3.0	348	13.9	47					
43	4	0	7	350	19	30				
		3.1	337	14.4	48					
44	3	0	7	355	19	30				
		4.0	351	13.9	47					
45	3	5	7	350	19	30				
		4.2	334	14.4	48					
46	3	345	7	350	19	30				
		4.0	354	14.4	48					
47	3	355	7	350	19	30				
		4.0	346	14.4	48					
48	3	355	6	350	19	30				
		3.9	345	14.9	45					
49	3	350	7	350	19	30				
		4.0	350	14.4	48					
50	3	355	7	350	19	30				
		4.0	346	14.4	48					
51	4	355	7	350	19	30				
		3.0	343	14.4	48					
52	3	355	7	350	19	30				
		4.0	346	14.4	48					
53	3	0	6	355	18	30				
		3.0	350	13.5	45					
354	3	0	6	350	18	30				
		3.1	340	14.0	46					

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DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1 Mag	1 Dir	2 Mag	2 Dir	3 Mag	3 Dir	4 Mag	4 Dir	
Time est 355	3	355	7	350	18	30				
		4.0	346	13.4	50					
56	4	355	7	355	18	30				
		3.0	355	12.9	48					
57	3	355	7	355	18	30				
		4.0	355	12.9	48					
58	4	355	7	350	18	30				
		3.0	343	13.4	50					
59	3	345	7	350	18	25				
		4.0	354	12.9	43					
400	3	350	7	350	18	25				
		4.0	350	12.9	43					
01	3	355	7	350	18	25				
		4.0	346	12.4	43					
02	3	0	8	345	18	25				
		5.2	336	12.9	48					
03	5	0	7	345	18	25				
		2.5	314	13.4	45					
04	4	0	7	350	18	25				
		3.1	337	12.9	43					
05	4	5	7	350	18	30				
		3.2	332	13.4	50					
06	3	355	7	350	18	30				
		4.0	336	13.4	50					
07	3	5	7	355	18	30				
		4.1	348	12.9	48					
08	3	0	7	355	18	30				
		4.0	351	12.9	48					
409	3	0	6	355	19	30				
		3.0	350	14.5	44					

DETAILED WIND SHEAR ANALYSIS

Year 1967 Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 410	3	0	7	355	19	30				
		4.0	351	13.9	47					
11	3	0	6	355	19	30				
		3.0	350	14.5	44					
12	2	355	6	355	19	30				
		4.0	355	14.3	44					
13	2	355	6	355	19	30				
		4.0	355	14.5	44					
14	3	355	6	350	19	30				
		3.0	345	14.9	45					
15	4	350	6	350	18	30				
		2.0	350	14.0	46					
16	4	355	6	350	18	25				
		2.1	340	14.0	46					
17	4	0	6	350	18	25				
		2.2	331	14.0	46					
18	4	355	6	350	18	25				
		2.1	340	14.0	46					
19	4	355	6	350	18	25				
		2.1	340	14.0	46					
20	4	0	6	350	18	25				
		2.2	331	14.0	46					
21	5	355	7	345	18	25				
		4.1	338	13.4	45					
22	4	350	7	345	18	25				
		3.0	338	13.4	45					
23	3	355	8	350	18	25				
		5.0	347	12.3	47					
4 24	4	355	7	345	18	25				
		3.1	322	13.4	45					

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DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 425	4	350	7	345	18	20				
		3.0	338	12.9	38					
26	4	350	7	345	18	20				
		3.0	338	12.9	38					
27	3	350	7	345	18	20				
		4.0	341	12.9	38					
28	2	355	7	345	18	20				
		5.0	341	12.9	38					
29	3	0	8	345	18	20				
		5.2	336	12.3	42					
430	3	0	8	345	18	20				
		5.2	336	12.3	42					
31	3	355	7	340	18	20				
		4.2	329	13.4	40					
32	4	355	7	340	18	20				
		3.3	322	13.4	40					
33	4	355	8	340	18	20				
		4.3	326	12.9	43					
34	4	350	8	340	18	20				
		4.1	330	12.9	43					
35	4	355	7	340	18	20				
		3.3	322	13.4	40					
36	4	355	8	345	18	20				
		4.1	335	12.3	42					
37	4	0	8	340	18	20				
		4.5	322	12.9	43					
38	4	355	8	345	18	20				
		4.1	335	12.3	42					
439	4	355	8	345	18	20				
		4.1	355	12.3	42					

DETAILED WIND SHEAR ANALYSIS

Year 1967 Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 440	4	355	8	345	18	20				
		4.1	335	12.3	42					
41	4	355	8	345	18	20				
		4.1	335	12.3	42					
42	5	355	8	345	18	20				
		3.2	329	12.3	42					
43	4	355	8	345	18	20				
		4.1	335	12.3	42					
44	4	355	8	345	18	20				
		4.1	335	12.3	42					
45	4	0	8	340	18	20				
		4.5	322	12.9	43					
46	4	0	7	345	18	20				
		3.3	327	12.9	38					
47	5	0	7	340	18	20				
		2.9	303	13.4	40					
48	4	355	8	340	18	20				
		4.3	326	12.9	43					
49	5	355	8	345	18	20				
		3.2	329	12.3	42					
50	4	0	5	345	18	20				
		4.3	331	12.3	42					
51	4	5	8	345	19	20				
		4.5	327	13.3	40					
52	4	355	7	345	18	20				
		3.1	332	12.9	38					
53	5	355	8	345	18	20				
		3.2	329	12.3	42					
454	4	355	8	345	18	20				
		4.1	335	12.3	42					

DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 455	4	355	8	345	18	20				
		4.1	335	12.3	42					
56	4	350	8	345	18	20				
		4.0	340	12.3	42					
57	5	0	8	345	15	20				
		3.4	323	12.3	42					
58	4	355	8	345	18	20				
		4.1	335	12.3	42					
59	4	0	8	345	18	20				
		4.3	331	12.3	42					
500	4	355	7	345	18	20				
		3.1	332	12.9	38					
01	4	355	8	345	18	20				
		4.1	335	12.3	42					
02	4	350	8	340	17	20				
		4.1	330	12.0	45					
03	3	0	8	340	18	20				
		5.3	329	12.9	43					
04	3	5	8	340	18	20				
		5.4	327	12.9	43					
05	3	355	7	345	18	20				
		4.1	338	12.9	38					
06	4	355	8	340	18	20				
		4.3	326	12.9	43					
07	4	350	8	340	18	20				
		4.1	330	12.9	43					
08	4	350	8	340	18	20				
		4.1	330	12.9	43					
509	4	350	8	340	18	20				
		4.1	330	12.9	43					

DETAILED WIND SHEAR ANALYSIS

Year 1967 Month 9 Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 510	4	350	8	340	18	20				
		4.1	330	12.9	43					
11	3	355	8	340	18	20				
		5.2	331	12.9	43					
12	3	355	8	340	18	20				
		5.2	331	12.9	43					
13	3	355	7	340	18	20				
		4.2	329	13.4	40					
14	3	0	7	340	18	20				
		4.3	326	13.4	40					
15	3	355	7	340	18	20				
		4.2	329	13.4	40					
16	3	350	7	340	18	20				
		4.1	333	13.4	40					
17	3	350	7	335	18	20				
		4.2	324	14.0	41					
18	2	350	8	335	18	20				
		6.1	330	13.6	45					
19	3	350	7	335	18	20				
		4.2	324	14.0	41					
20	3	350	7	335	18	20				
		4.2	324	14.0	41					
21	3	350	7	335	18	20				
		4.2	324	14.0	41					
22	3	355	7	340	18	20				
		4.2	329	13.4	40					
23	3	355	8	340	18	20				
		5.2	331	12.9	43					
524	3	350	8	340	18	20				
		4.1	333	13.4	40					

	4.1	338	13.4	43

DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 525	3	355	8	340	18	20				
		5.2	331	12.9	43					
26	3	350	7	340	18	20				
		4.1	333	13.4	40					
27	3	350	6	340	18	20				
		3.1	330	14.0	36					
28	3	355	7	335	18	20				
		4.3	321	14.0	41					
29	3	355	7	335	18	20				
		4.3	321	14.0	41					
530	3	345	7	340	18	20				
		4.0	336	13.4	40					
31	3	350	7	340	18	20				
		4.1	333	13.4	40					
32	3	350	7	340	18	20				
		4.1	333	13.4	40					
33	3	345	7	335	18	20				
		4.1	338	14.0	41					
34	3	355	7	340	18	20				
		4.2	329	13.4	40					
35	3	350	7	355	18	20				
		4.2	324	14.0	41					
36	3	350	7	340	18	20				
		4.1	333	13.4	40					
37	3	350	7	340	18	20				
		4.1	333	13.4	40					
38	3	355	7	340	18	15				
		4.2	329	12.9	33					
539	3	350	8	340	18	15				
		5.1	334	12.3	37					

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DETAILED WIND SHEAR ANALYSIS

Year 1967 Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est	2	350	8	340	17	15				
540		6.0	337	11.4	39					
41	4	345	8	340	17	15				
		4.0	335	11.4	39					
42	3	350	8	335	17	15				
		5.2	336	12.0	40					
43	3	350	8	335	18	15				
		5.2	326	12.9	38					
44	4	350	8	335	18	15				
		4.3	321	12.9	38					
45	4	355	10	340	18	15				
		6.2	330	11.4	45					
46	4	355	9	340	17	15				
		5.2	324	10.9	43					
47	3	355	9	340	18	15				
		6.2	333	11.8	41					
48	4	0	8	340	17	15				
		4.5	322	11.4	39					
49	4	350	9	340	17	15				
		5.1	332	10.9	43					
50	4	355	8	340	18	15				
		4.3	326	12.3	37					
51	3	350	9	340	18	15				
		6.1	335	11.8	41					
52	3	350	8	340	17	15				
		5.1	334	11.4	39					
53	4	350	7	340	17	15				
		3.1	327	12.0	35					
554	4	350	7	340	17	15				
		3.1	327	12.0	35					

DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 555	4	345	7	335	17	15				
		3.1	322	12.5	36					
56	4	355	8	335	17	15				
		4.5	317	12.0	40					
57	5	350	8	340	17	15				
		3.2	324	11.4	39					
58	5	345	7	340	17	15				
		2.1	328	12.0	35					
59	4	350	8	335	17	15				
		4.3	321	12.0	40					
600	4	345	8	330	16	15				
		4.3	316	11.8	44					
01	4	345	8	330	16	15				
		4.3	316	11.8	44					
02	4	345	8	330	17	15				
		4.3	316	12.7	42					
03	4	345	8	330	17	10				
		4.3	316	12.0	35					
04	3	350	8	325	17	15				
		5.4	312	13.4	42					
05	4	350	8	325	16	15				
		4.7	304	12.5	44					
06	4	345	8	325	16	15				
		4.5	307	12.5	44					
07	4	350	7	325	16	15				
		3.8	298	12.7	40					
08	4	340	8	330	16	15				
		4.1	320	11.8	44					
609	4	350	7	325	16	15				
		3.8	298	12.7	40					

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DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 610	3	345	8	325	15	15				
		5.3	314	11.6	47					
11	4	345	8	325	16	15				
		4.5	307	12.5	44					
12	4	340	8	330	16	15				
		4.1	320	11.8	44					
13	4	345	9	330	17	15				
		5.2	319	12.4	46					
14	4	350	8	330	17	15				
		4.5	312	12.7	42					
15	4	345	8	330	17	15				
		4.3	316	12.7	42					
16	4	355	8	330	17	15				
		4.7	309	12.7	42					
17	4	350	8	330	17	15				
		4.5	312	12.7	42					
18	4	350	8	330	16	15				
		4.5	312	11.8	44					
19	4	350	8	335	16	15				
		4.3	321	11.1	43					
20	4	355	8	335	16	10				
		4.5	317	10.5	36					
21	4	355	8	335	17	15				
		4.5	317	12.0	40					
22	4	345	7	335	17	15				
		3.1	322	12.5	36					
23	5	345	8	335	17	15				
		3.2	319	12.0	40					
624	5	350	8	335	17	15				
		3.4	313	12.0	40					

DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1 Mag	1 Dir	2 Mag	2 Dir	3 Mag	3 Dir	4 Mag	4 Dir	
Time est 625	4	350	8	340	16	15				
		4.1	330	10.5	41					
26	4	350	9	335	17	10				
		5.2	324	10.9	38					
27	4	345	8	335	17	10				
		4.1	325	11.4	34					
28	5	350	8	335	17	10				
		3.4	313	11.4	34					
29	5	345	9	330	18	10				
		4.4	313	12.5	38					
630	4	350	8	330	18	10				
		4.5	312	12.9	33					
31	5	345	9	330	18	10				
		4.4	313	12.5	38					
32	4	350	9	330	18	10				
		5.4	315	12.5	38					
33	4	345	8	330	18	5				
		4.3	316	12.3	27					
34	5	345	8	330	18	5				
		3.4	308	12.3	27					
35	5	340	7	330	18	5				
		2.3	307	12.9	23					
36	4	345	8	330	17	5				
		4.1	320	11.4	29					
37	3	350	8	330	18	5				
		5.3	319	12.3	27					
38	3	345	8	330	17	5				
		5.3	319	12.3	27					
639	3	345	8	330	17	5				
		5.2	321	11.4	29					

DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 640	4	345	7	330	17	5				
		3.3	312	12.0	25					
41	4	345	7	325	17	5				
		3.5	302	12.5	26					
42	4	340	7	330	17	5				
		3.1	317	12.0	25					
43	5	345	7	325	17	5				
		2.9	288	12.5	26					
44	5	355	8	330	16	5				
		4.1	299	10.5	31					
45	4	355	7	330	16	5				
		3.8	303	11.0	26					
46	4	345	7	330	16	5				
		3.3	312	11.0	26					
47	3	355	7	325	16	5				
		4.7	306	11.6	28					
48	3	350	6	330	16	5				
		3.3	312	11.6	22					
49	3	355	6	330	16	5				
		3.5	309	11.6	22					
50	3	355	6	330	16	5				
		3.5	309	11.6	22					
51	3	345	6	330	16	5				
		3.2	316	11.6	22					
52	3	350	5	320	16	5				
		2.8	288	13.0	21					
53	3	350	5	330	16	5				
		2.4	305	12.2	19					
654	3	345	6	330	16	5				
		3.2	316	11.6	22					

DETAILED WIND SHEAR ANALYSIS

Year 1967 / Month 9 / Day 15

Wind Level	1		2		3		4		5	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
Shear Level		1		2		3		4		
		Mag	Dir	Mag	Dir	Mag	Dir	Mag	Dir	
Time est 655	3	340	6	335	16	5				
		3.0	330	11.2	21					
56	3	0	6	335	16	5				
		3.5	314	11.2	21					
57	3	350	6	330	16	5				
		3.3	312	11.6	22					
58	2	350	6	335	16	5				
		4.1	328	11.2	21					
59	2	350	6	330	17	5				
		4.2	321	12.6	21					
700	3	340	6	330	16	5				
		3.1	320	11.6	22					
01	3	350	6	330	16	5				
		3.3	312	11.6	22					
02	3	335	6	330	16	5				
		3.0	325	11.6	22					
03	5	355	5	325	15	5				
		2.6	250	11.6	21					
04	4	350	7	330	15	5				
		3 5	307	10.1	28					
05	3	350	7	350	15	5				
		4.3	316	10.1	28					
06	3	345	6	335	15	5				
		3.1	325	10.3	22					
07	3	345	6	330	15	5				
		3.2	316	10.7	24					
08	2	355	6	325	15	5				
		4.4	312	11.1	25					
09	3	345	6	330	14	0				
		3.2	316	9.3	19					
710	3	340	6	330	14	0				
		3.1	320	9.3	19					

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Case of December 13, 1968

The period of interest in this case is 0425 to 0625 EST. This was selected out of a period when shears were present from 2025 December 12, 1968 to 0925 December 13, 1968. During this longer time shears were present intermittently. In this period 0425-0625 shears were present almost continuously at the 3rd and 4th levels. At the same time there was an inversion of greater than $2^{\circ}F/100$ ft. at the 4th level.

A. General Synoptic Situation

At 2200 EST of December 12, 1968, a deep low pressure area was centered over western Wisconsin. A stationary front extended eastward out of the low to the junction of Lake Superior and Huron. A cold front extended southward from the low through central Illinois and then along the Mississippi River. A ridge of high pressure oriented NE-SW lay off the North eastern coast of the U.S. and entered the coast over North Carolina. This caused the prevailing flow to be SW to NE over the eastern U.S.

By 0400 E the only change in the situation was the eastward movement of the cold front to central Indiana and the occlusion of the wave which was now centered over upper Wisconsin. At 0700 E, December 13, 1968 the ridge of high pressure still persisted over the north eastern U.S. The cold front had moved to Western Ohio.

Well defined south westerly flow dominated the eastern part of U.S. with showers ahead of the cold front.

The surface weather reports in the vicinity of Philadelphia indicated few clouds to clear skies over the area and visibility generally better than 7 miles except for 4 to 6 miles in smoke at NAS Willow Grove.

Surface winds at Philadelphia were light and variable, less than 5 kts. becoming south to south westerly 7 to 8 kts. at the end of the period. The same pattern existed at the other station except for Reading, Pa. where the wind was calm until 1000 EST.

B. Temperature Inversions

Temperature inversions of greater than $2^{\circ}F/100$ ft. with wind shears greater than 12 kts. occurred at level 4 for one hour during this period.

Temperature Inversion
$F^{\circ}/100$ ft.

	Level	1	2	3	4
Time	0325	1.5	-0.1	0.4	2.1
	0355	0.7	-0.1	0.1	2.0

There was a strong radiational cooling inversion of $10^{\circ}F/100$ ft. and $12^{\circ}F/100$ ft. at the above times between the surface (5 ft.) and 40 ft.

C. Detailed Analysis of Wind Shears

From the analog records of the Aerovane Anemometers, a minute by minute tabulation of the wind shears at the four levels on the tower were made. This table is attached. The ten minute wind shears at level 4 were 14 and 15 kts. at the time of the inversion. The shears at level 3 also exceeded the minimum at 10 kts. during the hour.

The one minute shear analysis shows that no shears exceeded the minimum at level 1 and only momentarily on several occasions at level 2. These shears occurred toward the end of the period 1556 to 0622. The shears at level 3 began to exceed 8 kts. at 0427 and became persistent and stronger after that. The maximum one minute shear at level 3 was 14.6 kt. at 0453 EST. The shears at level 4 exceeded 10 kts. most of

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the time from 0425 to 0625 with a maximum value of 14.3 kts. at 0425 E. The direction of the shears were consistent. 160^{o} to 200^{o} at level 1 veering to 190^{o} to 210^{o} at level 2. 210^{o} to 230^{o} at level 3 and 220^{o} to 250^{o} at level 4.

Detailed Wind Shear Analysis sheets omitted from this case study to reduce volume.

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Case of May 8, 1970

This is a situation in which shears occurred in conjunction with inversions from 2140 to 2325 EST.

A. General Synoptic Situation

At 1900 E of May 8, 1970 a high pressure area was centered about 300 miles east of Jacksonville, Fla. A low pressure center south of Hudson Bay in Canada had a cold front southward through Lake Huron, Central Indiana, and through St. Louis, Mo. By 0100 E, May 9, 1970, the cold front had moved to Erie, Pa. and north westward. The high pressure area was still east of Jacksonville, Fla. The wind flow over Southeastern, Pa. was southwesterly.

There were thin high clouds over the area of Philadelphia until midnight of May 8, 1970. Visibility was better than 7 miles. Surface winds were soutwest 5 to 8 kts.

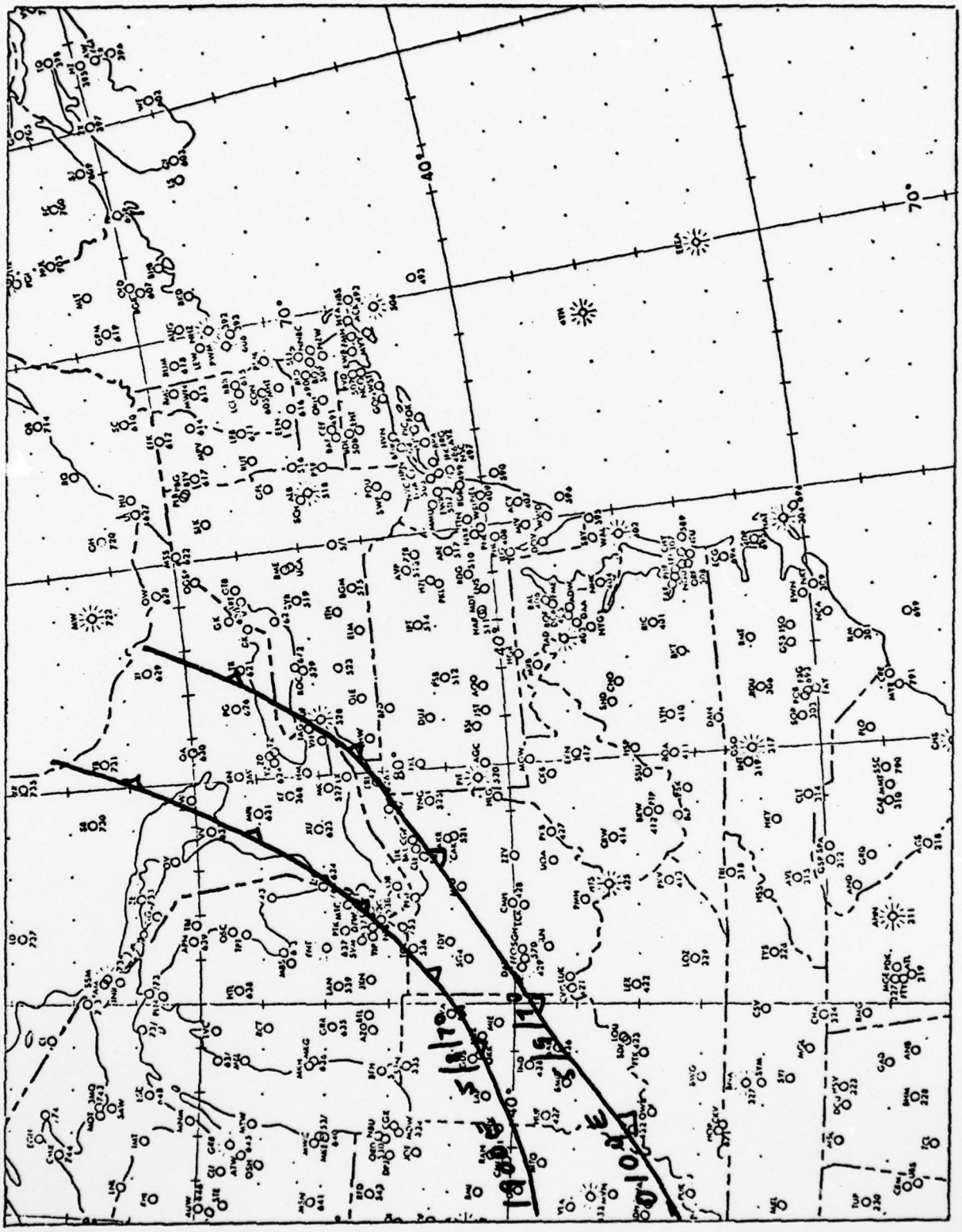
B. Temperature Inversion

Lapse rates with temperature inversions greater than $2^{\circ}F/100$ ft. occurred at level 4 during the period. In addition the lapse rate from the surface to 40 ft. was $3.4^{\circ}F/100$ ft. or higher while the lapse rates at levels 1, 2, and 3 were less than $2^{\circ}F/100$ ft.

		Temperature $F^{\circ}/100$ ft.			
	Level	1	2	3	4
Time	2255	0.7	-0.2	0.8	2.1
	2310	0.7	-0.1	1.0	2.0
	2325	0.5	-0.1	0.9	2.0

C. Detailed Analysis of wind shears.

A minute by minute determination of wind shears from 2140 to 2335 of May 8, 1970 is attached. Only data for levels 1 and 4 were available and only level 4 had shears meeting the minimum criteria.



Detailed Wind Shear Analysis sheets omitted

from this case study to reduce volume.

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Correlation of Thunderstorm Data and Corresponding Temperature Drop and Maximum Wind Gust

Using the surface weather observations of the Philadelphia International Airport, the days on which thunderstorms were reported were identified. The analog wind and temperature records for the 100 ft and 890 ft elevations were examined to determine the time and magnitude of the temperature drop, if any, that occurred at the apparent time of the thunderstorms and the magnitude and time of the maximum gust that occurred in conjunction with the temperature drop.

In addition, the time of beginning and ending of sustained winds equal to or greater than 30 kts was recorded for levels 100 ft and 890 ft if they reached those values.

In all, records for 76 separate thunderstorms could be identified. The correlating data are listed below.

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	Date	100 ft Time (EST)	100 ft Temp Drop (°F)	100 ft Max Gust (kts)	100 ft Duration of Wind 30 kts	890 ft Time (EST)	890 ft Temp Drop (°F)	890 ft Max Gust (kts)	890 ft Duration of Wind 30 kts
1	5/2/65	0113		17	none	0009		25	none
		0120	2			0110	5		
2	5/16/65	1959		36	none	1955	7	48	1955-2005
		2000	6						2018-2022
3	5/27/65	1540	15		none	1540	14		1537-1618
		1544		41		1550		49	
4	6/2/65	1735	14		none	1735	15		1737-1750
		1742		39		1740		42	
5	6/8/65	1445		20	none	1520	4		none
		1520	5			1538		22	
6	6/10/65	1324		22	none	1410	4		none
		1400	7			1420		27	
7	6/19/65	1540	15		none	1540	10		1645-1647
		1557		24		1556		25	
8	6/23/65	2115	10		none	2105	11		none
		2120		30		2115		30	
9	7/11/65	0128		20	none	0120	6		none
		0130	2			0133		21	
10	7/18/65	1535	8		none	1540	4		none
		1601		20		1612		20	
11	7/18/65	1750	11		none	1750	8		1755-1812
		1805		34		1805		48	
12	11/17/65	-				0222		40	11/16-2200
		-				0223	4		11/17-0240
13	2/13/66	1634		30	none	1623		46	1500-1640
		1715	2			1740	2		
14	1/27/67	1318		37	none	1317		54	1010-1330
		1340	2						
15	3/15/67	0155	3		none	0155	2		
		0233		21		0238		29	none
16	5/8/67	1920	5		none	1920	6		none
		1930		22		1933		34	
17	5/15/67	1930	2		none	1910	2		2020-2035
		2044		30		2025		36	
18	5/19/67	1650	3		none	1650	3		1723-1727
		1710	10			1715	11		
		1725		32		1723		40	

19	6/22/67	1520		25	none	1540	3		none
		1530	4			1643		33	
20	6/25/67	1653		22	none	1655	3		none
		1655	2			1656		30	
21	7/3/67	0500	3		none	0505	3		none
		0511		16		0520		18	
22	7/10/67	1635	5		none	1558		18	none
		1650		18		1635	4		
23	7/11/67	1528	0	13	none	1505	2		
						1525		14	none
24	7/21/67	1745	4		none	1735	2		
		1753		25		1751		26	none
25	7/25/67	0020	6	28	none	0015	7		0036-0038
						0018		38	
26	7/29/67	2010	4		none	2005	4		none
		2045		12		2045		12	
27	7/31/67	1750	4		none	1750	2		none
		1758		16		1757		18	
28	8/3/67	0900	6		none	0900	0		none
		1038		29		1035		32	
29	8/3/67	1430	0	16	none	1435	6		none
						1448		20	
30	8/9/67	2020	3		none	2000	6		none
		2048		22		2043		30	
31	8/19/67	1630	3		none	1655	3		none
		1658		16		1716		22	
32	8/20/67	0025	0	14	none	0005		27	none
						0010	3		
33	8/26/67	2300	2		none	2250	4		none
		2305		17		2255		27	
34	8/27/67	1235	10		none	1255		18	none
		1257		23		1300	5		
35	9/21/67	1940	6		none	1940	1		
		2047		27		2053		37	none
36	9/24/67	1645	7	26	none	1645	6		none
						1647		33	
37	10/18/67	1815	9			1815	11		
		1817		42	1817-1818	1818		58	1700-1933
38	11/12/67	1525	12		none	1530	12		1526-1540
		1528		3		1528		40	
39	12/12/67					0250	2		none
						0258		21	
40	5/16/68	2240		18	none	2240	4		none
		2300	1			2308		32	
41	5/20/68	1406		20	none	1410	6	0	none
		1410	9						
42	6/3/68	0000	6		none	2358		35	none
		0205		14		0000	3		
43	6/9/69	0134	0	18	none	0030	2		none
						0146		30	

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44	6/15/69	1410	10		none	1410	7		1442-1444
		1445		29		1443		45	
45	7/12/69	1600	10		none	1600	10		1605-1613
		1607		37		1606		59	
46	7/18/69	1635	8		none	1640	5		none
		1650		12		1645		17	
47	7/27/69	2245	8		none	2245	7		none
		2256		27		2252		30	
48	7/28/69	1455	6		none	1427		33	nine
		1502		20		1500	5		
49	8/9/69	1845	3		none	1840	2		none
		1851		17		1853		18	
50	8/10/69	2310	4		none	2255	0		none
		0017		21		0028		29	
51	10/21/69	0030	8	43	none	0010	9		0013-0033
						0030		48	
52	11/14/69	1830	10	40	1830-1833	1830	9		1832-1848
						1832		42	
53	4/2/70	1515		38	none	1408		60	0947-2359
		1650	9			1515	8		
54	4/9/70	1455	16		none	1455	16		1505-1514
		1457		33		1506		44	
55	4/24/70	0955	0	22	none	0950	9		0947-0956
						0953		35	
56	5/19/70	1830	12		none	1830	11		none
		1858		27		1858		29	
57	5/23/70	1535	5		none	1530	5		none
		1538		19		1542		19	
58	5/26/70	1625	8		none	1625	4		none
		1627		20		1637		20	
59	6/3/70	1555	13		none	1555	12		none
		1601		32		1601		33	
60	6/6/70	1130	5		none	1130	4		none
		1135		16		1145		23	
61	6/12/70	1450	19		1524-1525	1450	16		1503-1515
		1525		50		1515		48	
62	6/18/70	1710	8		nine	1715	4		none
		1715		17		1727		18	
63	6/18/70	1911		21	none				
		1925	4						
64	6/21/70	1412		24	none	1350	0	34	1346-1353
		1505	6						
65	7/2/70	0020	4		none	0020	7	0	none
		0035		15					
66	7/10/70	1030	6		none	1107	0	24	none
		1103		18					
67	7/15/70	2120	10		none	2115	7		2143-2244
		2148		32		2144		42	
68	7/26/70	1500	10		none	1500	8		none
		1502		15		1502		20	
		2310							

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69	7/31/70	2310	5		none	2305	4		none
		2312		22		2310		23	
70	8/3/70	1900	7		none	1915	4	0	none
		1915		12					
71	8/9/70	1615	10		none	1615	9		none
		1620		24		1625		21	
72	8/14/70	1420	6		none	1420	6		none
		1423		20		1422		20	
73	8/16/70	1528		16	none	1525	4		none
		1530	6			1532		18	
74	8/17/70	1410	6		none	1410	4		none
		1428		22		1430		28	
75	8/23/70	0358		20	none	0350		30	0603-0620
		0400	3			0400	2		
76	8/23/70	1120	5			1125	5		none
		1130		18		1125		28	